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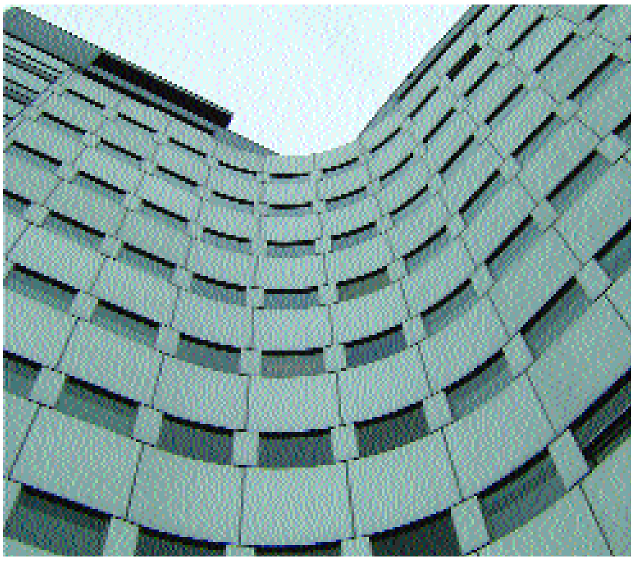
Core Technologies for the Cultural and Scientific Heritage Sector



Technology Watch Report 3

Information Society Technologies

Core Technologies for the Cultural and Scientific Heritage Sector

DigiCULT Technology Watch Report 3

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Introduction

This is the third Technology Watch Report (TWR3)[I]. It continues DigiCULT's work in providing heritage institutions with researched assessments of current and emerging information technologies that they can use in their efforts to expose, manage better, and make more accessible the wealth of our cultural heritage. It is the last TWR that The *Digital Culture Forum* (DigiCULT Forum, IST-2001-34898) will release under this funding stream. The DigiCULT team monitors research and technological developments with support from the European Commission's Information Society Technologies (IST) Programme under the 5th Framework Programme. The DigiCULT technology assessments identify developments that can be deployed without further work, those that would require further development or repurposing and those that are still some way away from having deployable implications but which show promise. The cultural heritage sector suffers from a lack of access to accurate, accessible, and relevant information about technological developments. We continue to use the word 'technology' in its broadest sense to cover methods (e.g. information retrieval, visualisation) and procedures, standards, hardware (e.g. RFID), and software applications.

As in previous TWRs, this volume examines six core technologies. Those covered here underlie a wide range of future applications of technology. These include *Open Source*, Natural Language Processing (NLP), Information Retrieval (IR) technologies, Location Based Systems (especially GIS and GPS), visualisation of data, and telepresence, haptics and robotics. This report builds on our earlier two reports. TWR1 (2003) examined Customer Relationship Management Systems (CRM), Digital Asset Management Systems (DAMS), Virtual Reality (VR), Human Computer Interface (HCI) technologies, Smart Tags and Labels, and Games. These are all technologies which improved how institutions could manage their assets, whether analogue or digital, and improve the services they provided to their visitors/users. TWR2 (2004) examined technologies that improve interoperability between sectors, standards that promote long term viability of resources, approaches that support personalise experiences of the heritage and those that support access to shared spaces, and mechanisms that enable curators and users of the heritage to participate in enriched real and virtual environments.

Technology develops quickly and the heritage sector needs to identify those technologies that will bring benefits and have a certain amount of sustainability over a reasonable horizon. The TWRs attempt to do just this. We have covered these technologies discretely, although we have attempted to indicate links between them or the benefits of using a number of the technologies together. The real opportunities to heritage institutions will come from the marriage of the different technologies. This is a topic which DigiCULT hopes to examine further in its 2005 work programme.

I S Ross, M Donnelly, and M Dobreva, 2004, *Emerging Technologies for the Cultural and Scientific Heritage Sector*, DigiCULT Technology Watch Report 2, European Commission, ISBN 9289452765; S Ross, M Donnelly, and M Dobreva, 2003, *New Technologies for the Cultural and Scientific Heritage Sector*, DigiCULT Technology Watch Report 1, European Commission, ISBN 9289452757.

In the introduction to TWR1 (2003), *New Technologies for the Cultural and Scientific Heritage Sector*, we described the mechanisms DigiCULT uses to select, evaluate, investigate, and present technologies.[II] Readers of this report are encouraged to take a look at the methodology we laid out there as it underpins this current work. We developed this methodology to ensure that we were providing the cultural heritage community with access to accurate, accessible information about current, near- and longer-term technological developments. These technologies were placed in the context of case studies based on investigations of the experiences of institutions that had begun experimenting with newer technologies. We have found the case studies to be valuable indicators of how the sector imaginatively adapts new technologies as they adopt them. The range of cultural and scientific heritage institutions is broad and to indicate a wider array of ways these technologies might be employed we have supplemented our case studies of applications with scenarios that suggest other kinds of applications for these technologies. Throughout this process we provided opportunities for the community to participate in shaping these reports through providing case studies and by making draft versions of each of the Briefings that make up these TWRs available online for expert comment. This has proved valuable and it has provided us with essential community input into our work. It is fair to say that the methods which underlie our work have become more refined since the start of the project, but essentially the process of working we laid out in TWR1 has provided us with a solid framework for building these reports.

While we have worked to ensure that the TWRs are up-to-date at the time of their publication and this is a fast changing environment. The TWRs belong to a basket of deliverables which DigiCULT creates and manages for the cultural heritage community. In addition to these Technology Watch Reports DigiCULT has produced a series of themed studies of technology built on expert discussion, the *DigiCULT.Info Newsletter* (now our ejournal) and a participatory web site (http://www.digicult.info). The latter, a community driven web site, has become a core feature of DigiCULT's information resource by providing online access to all DigiCULT's publications and by offering a wide range of other information services. Among these are details of events, resources of value to the community, CVs of practioners, a jobs service, and a RSS newsfeed. The DigiCULT team will continue to add additional services to ensure the long term value of the website to our community. Through *DigiCULT.Info* and our website we are able to provide the community updates on issues covered in the TWRs. Readers of these reports should turn to these other sources as well.

The Technologies Covered in this Report

The dependence of most institutions on proprietary software products, as for example the Microsoft family of applications, does not provide them with reasonable cost models or long term sustainability options for the digital materials they create with those products. The *Open Source* software movement builds on the twin principles of free software availability and a community-based approach to software development. The community of Free and Open Source software (often abbreviated to OSS, or FOSS) developers has delivered a rich array of alternatives to proprietary commercial software. These open source products are low (if not no) cost applications. They are realistic, robust, and fully functional alterna-

II S Ross, M Donnelly, and M Dobreva, 2003, *New Technologies for the Cultural and Scientific Heritage Sector*, DigiCULT Technology Watch Report 1, European Commission, ISBN 9289452757, 11-15.

tives to proprietary commercial products. Furthermore, a wide range of quantitative evidence has demonstrated that Open Source offers excellent value in terms of total cost of ownership (TCO). Open Source products alleviate opaqueness in product design, which poses an obstacle to the exchange across space and time of digital objects created with closed commercial products. The main beneficiary of open source products is institutional and individual user, and not commercial investors. The case studies such as the deployment of *LinEX* by Extremadura region of Spain which began in 2002 and the implementation by the **Historisches Museum** in Basel, Switzerland of an Open Source system to deliver a flexible, portable, and adaptable collection documentation system for museums, private collectors and galleries (known as *myColex*), clearly show the possibilities. The final case study examines *Gamera*, a programming toolkit for building document recognition applications. Each of these case studies approaches the open source domain from a different point of view. In the first we observe the process involved in rolling out an open source suite of business applications to a public sector organisation. In the second we see how in developing its own services heritage institutions can contribute to creating open source applications and in the third we observe how open source building blocks can be created, tailored and used to deliver new applications.

The family of technologies wrapped under the umbrella term Natural Language Processing (NLP) investigates mechanisms to enable computers to understand (or 'parse') the meaning of ordinary language. By way of example an NLP system might be used to convert spoken words into text or to establish the linguistic meaning of a sentence and transform it in ways that would enable it to initiate an action. This is a complex task influenced by a range of factors from the presence of idioms and non-standard vocabulary, to words which sound identical but have different spellings or meanings, and impacted by the fact that the majority of human communication is non-verbal. Although research has been intensive in this area the current generation of NLP technologies are best applied in restricted environments and involving narrow vocabularies. The applications of the technology include extraction and formatting of information based on unstructured text, automated language translation, conversational dialogue systems, a broad group of human language technologies that such as speech recognition, voice pattern verification and text-to-speech conversion, and a whole class of text analysis and language engineering applications ranging from browsing and querying to summarisation. Corporate research investment in the arena continues to be substantial. In some areas the rewards to come from successfully deployed products will be substantial; no more is this true than in the area of multilingualism as real-time machine-automated translation between languages.


(c) HATII, University of Glasgow, 2004

The Grave of George Boole (nr Cork, Ireland)

The applications to the cultural heritage could be transformative in terms of access and use of heritage assets these technologies could make possible. MUSA (MUltilingual Subtitling of multimedia) is investigating systems for combining speech recognition, advanced text analysis, and machine translation to help generate multilingual subtitles automatically. The system converts audio streams into text transcriptions, condenses and/or re-phrases the content to meet the spatio-temporal constraints of the subtitling process (for example that there is a limit to the number of characters that can appear on the screen at any one time), and produces draft translations in at least two language pairs. It is easy to see how this kind of technology would be of immense value in heritage institutions. Another project, M-PIRO (Multilingual Personalised Information Objects) focused on develop the language engineering aspects of Personalised

Information in virtual and other museum settings, with particular regard to its delivery across different languages. Relatively recent work between the University of Edinburgh and the Royal Commission for Historical Monuments for Scotland, not examined here, is worthy of note because it is examining how NLP technologies can be used to tailor the delivery of content stored in databases in meaningful ways to different users of different ages and educational attainments.

NLP has strong links with Information Retrieval (IR) technologies more generally. IR is widely used and it is indeed second only to email in terms of users' online activities. Searching, data mining, content-based multimedia retrieval, automatic summarisation, and personalisation of information are all examples of IR technologies. All these techniques are central to the reliable and efficient discovery and access of cultural and scientific content. The complexity of retrieval technologies vary. Searching for a basic string search in an electronic text is relatively simple, for instance. Others searches in the text-based arena are more complex and depend upon defining relevance by number of occurrences, use of Boolean operators to frame search constructions, mechanisms to retrieve results from overlapping results sets and the commonly used 'Google-approach' of using hyperlinks to determine relevance. Content-based retrieval and summarisation are two areas that will enable increasingly effective and efficient discovery. The wider use of this technology will improve how the cultural heritage can discover objects and may reduce the amounts of metadata that need to be added to digital objects. Research in IR has increasingly focused on non-textual media which has proved extremely complex, although current studies of image colour analysis, audio or visual 'cues' in digital video, and shape recognition are showing some promise.

The sciences make widespread use of distributed retrieval and data mining. Until recently, the cultural heritage sector has been concerned with issues surrounding text retrieval and metadata and only more recently shown an interest in content-based media retrieval. Improvements to the accuracy, efficiency and reliability of basic searching/retrieval tasks, text and multimedia searching, freeing content from the metadata required for its retrieval, and enabling personalisation of searching. With these improvements IR technologies are proving of greater value to investigations of the digital cultural heritage. Information Retrieval is a very diverse domain and the section of TWR3 devoted to IR investigates retrieval strategies rather than the functions of specific software packages. The scenarios and case studies demonstrate the tremendous potential of these developments. MuchMore (Multilingual Concept Hierarchies for Medical Information Organisation and Retrieval) provides a framework for developing new approaches to *cross-lingual information retrieval* (CLIR). Although this project has targeted the medical domain, it demonstrates the effective combination of both heterogeneous resources and retrieval approaches, the possibilities of automated acquisition of domain-specific linguistic resources, and the potential of cross-lingual access to information through the combined use of corpus analysis and a domain-ontology. Solutions in this area could demonstrate the viability of solutions in the cultural heritage as the shape of the domains and their complexity are not too dissimilar. Another case study looks at the Vikings Project which aims to develop new content-based retrieval systems for searching databases of moving image and audio material. Public and commercial use of audio and video archives, whether in commercial or public settings, are greatly hampered by the lack of technologies to support the automatic off-line annotation and make annotation-free online search operations effective. In TWR2 DigiCULT reported on the possibilities of *Mobile Access to Cultural Information* and in TWR3 in a study of Location Based Systems we are further exploring technologies such as GPS (the Global Positioning System) and GIS (Geographic Information Systems). A GIS facilitates the visual representation of geographic features of digitally stored data. In response to queries a GIS turns user input into an explicit map location. Two approaches are used to store geographic data: vector graphics, a method in which linear data are stored as strings of x and y co-ordinates and raster graphics, which express data at pixel level as a grid-matrix of cells. It is generally agreed that the raster method is strongest at portraying subtle and gradual changes while vector graphics methods represent linear data more effectively. Of course real world problems can often benefit from a comparison of GIS representation models and to support analysis, manipulation and presentation this data in a variety of ways for different purposes. In the cultural sector the work of the **National Monuments Record of Scotland** (NMRS), which maintains a GIS database containing site details alongside location and bibliographic details, offers an excellent example of how powerful the tool can be for researchers by giving them access to archaeological data in visual ways that make it more accessible.

The GPS consists of twenty-four satellites that allow ground receivers to ascertain their spatial location. Each satellite continually broadcasts its changing position and time. GPS receivers triangulate their own position by taking bearings from three of the four visible satellites to provide a longitude and latitude position and the fourth satellite establishes the user's altitude. When the data are linked with dynamic mapping capabilities, such as that provided by a GIS, the location can be output visually in map form. The *Atlante Italiano* gives online access to the cartographic data for Italy represented from such different perspectives as the environmental risks of flooding or earthquake. The *ODIN Mobile* projected worked to establish paradigms for the design of open, distributed, and networked tools to boost the integration of interactive, value-added, map-based and personalised services for the mobile users with special focus on the natural and cultural assets of rural areas. A first case study looks at CHIMER (Children's Heritage Interactive Models for Evolving Repositories), which engaged children to build digital maps which combine GPS coordinates with the innovative use of new mobile technologies and digital cameras, linking photographs with the comments provided by the children themselves. Essentially they worked to generate a virtual Digital Heritage Archive of their own towns and communities.

As our examination of GIS systems makes evident digital data is often much easier to when represented visually than when it appears as raw data streams. *Visualisation* is the process of representing abstract information in the form of images designed to facilitate interpretation of data. Visualisation systems support the representation of substantial amounts of data, the ability to navigate and interact with the data, and it makes it easier to see patterns and trends in the data. Dynamic visualisation can create new ways of thinking, support new kinds of knowledge acquisition and decision-making. They give the user a tangible experience and in so doing may open visitors/users to changes and shifts in populations. Museums might use visualisation tools in conjunction with RFID to model the flows of visitors to see how the patterns alter (or do not alter) according to the time of year, the artefacts on show and even the signage within the building. As our case studies show, while visual information retrieval systems play an increasingly significant role in the ways we access, analyse, and understand information, most systems do not provide visual representation with contextualisation of the retrieved information. VICODI (Visual Contextualization of Digital Content) case study developed a methodology and tools for structuring and graphically visualising context to facilitate creation of new knowledge using historical maps and colour coded links. Music is a very significant cultural domain and own which to which we have shown little attention. The Music Animation Machine is using visualisations of music to help the non-musician appreciate the aspects of musical structure that are generally only understood by composers and theoreticians.

Finally a discussion of suite of interrelated technologies concludes TWR3. A review of telepresence, haptics and robotics shows how these technologies might open up a wide range of potential applications in the cultural and scientific heritage sectors. Giving real world users a sense of presence when they interface with a virtual environment breaks down the distinction between the virtual and the physical worlds. A rich array of devices small cameras, microphones, speakers, and head mounted displays can be combined to give users a feeling of telepresence at the interface between the physical and virtual worlds. *Haptic* technologies are another example of an approach that can be used to breakdown the barrier between the virtual and the physical worlds. It does this by establishing touch sensations in computing environments. Occasionally the technology is referred to as 'force-feedback'. Haptics is a device-driven technology with wide range of input/output peripherals available; pens, gloves, joysticks/joypads and force-feedback mice. Normally used in conjunction with a visual display, haptic devices enable users to manipulate virtual representations of objects and artefacts. An area related to telepresence and haptics is *Robotics*, the branch of engineering which involves the conception, design, manufacture and operation of machines designed to perform a particular task either under the direct control of a human operator or a computer.

In the heritage setting haptics can be used to allow visitors to museums (whether virtual or real) to handle virtual representations of priceless artefacts without subjecting the real objects to risk Applied this way haptics can be used to add an extra dimension to learning and exploration and to improve access to materials. Robotics and telepresence can be combined to provide virtual representations in distant museums/galleries to map uncharted terrain and compile data for virtual reality models. The three case studies in this section explore different aspects of telepresence, haptics, and robotics and their role in the heritage sector. Avatar Body Collision, for example, supports distributed and collaborative virtual performances across international boundaries. It provides a model for both collaborative performance and for interactive action. Another project in this area the Museum of Pure Form explored new paradigms of interaction with sculptures in a virtual gallery populated with three-dimensional sculptures which visitors could both see and touch virtually. The combination of these two senses changed the visitor's relationship with the works of art and their appreciation of them.

Conclusion

DigiCULT's TWRs have examined eighteen technologies in the past thirty months, but there are many core technologies and related topics that we have not touched on. Three overarching ones are worthy of mention: digital libraries, digitisation, and digital preservation. We have focused on technologies for transforming how content can be discovered and used, for enhancing and altering visitor experiences, improving and enriching curatorial practices, and how technology can enable the better management of cultural heritage and scientific institutions. Digital content, or eContent, creation and management will become an increasingly central aspect of the work of cultural heritage institutions. As Seamus Ross recently noted in a discussion of the Lund Principles:

> 'The cultural and scientific heritage of Europe held in our memory institutions provides a source of raw materials for economic, intellectual, social, and cultural development in the 21st century. The value of these raw materials multiplies when they are available in digital form. In digital form they can, as is widely recognized, serve as sustainable and renewable resources that can be exploited in an ever-increas-

ing diversity of ways. In their digital guise these materials provide core resources for enabling education, supporting life-long learning, underpinning the development of new products by creative industries, contributing to improvements in our quality of life, and through their virtual accessibility helping to foster tourism.'[III]

The Lund Principles were intended to encourage high quality, cooperative digitisation built on exemplary standards of practice.[IV] Digitisation certainly offers many possibilities to heritage institutions to improve access to their collections and we have carried articles in *DigiCULT.Info* examining it. We hope that DigiCULT will investigate as a core technology the topic in a future TWR. There is though much good guidance already available and here we call attention to:

- NISO Framework Advisory Group, (2004), A *Framework of Guidance for Building Good Digital Collections*, (Bethesda, MD: NISO Press), http://www.niso.org/framework/framework2.pdf

- The Humanities Advanced Technology and Information Institute (HATII), University of Glasgow, and the National Initiative for a Networked Cultural Heritage (NINCH), 2002. *The NINCH Guide to Good Practice in the Digital Representation and Management of Cultural Heritage Materials.* (Washington DC, NINCH), http://www.ninch.org/guide.pdf.

- North Carolina ECHO (*Exploring Cultural Heritage Online*). 2004. *Digitization Guidelines*. http://www.ncecho.org/Guide/2004/toc.htm.

- Technical Advisory Service for Images funded by the Joint Information Systems Committee in the United Kingdom manages a growing compendium of advice and guidance in the area of digital representation. http://www.tasi.ac.uk/

To these four we can also encourage use of the MINERVA resources. MINERVA was funded by the European Commission to support the take up of the Lund Principles and among its work it has published guidelines on digitisation and produced lists of sources of guidance and identified competence centres within Europe http://www.minervaeurope.org/guidelines.htm.

III S Ross, 2004 [forthcoming], 'Reflections on the Impact of the Lund Principles on European Approaches to Digitisation', delivered as a paper under the title 'Progress from National Initiatives towards European Strategies for Digitisation' at *Towards a Continuum of Digital Heritage: Strategies for a European Area of Digital Cultural Resources, European Conference* in Den Haag on 15-16 September 2004 organised by the Dutch Ministry of Education, Culture and Science conference in context of the Netherlands EU Presidency 2004.

IV Agreed 4 April 2001 in Lund (Sweden) http://www.cordis.lu/ist/directorate_e/digicult/lund_p_browse.htm, See also, S Ross (Rapporteur), 2001, *Report of an Expert Meeting on European Content in Global Networks, Coordination mechanisms for digitisation programmes*, Lund, Sweden. 4 April 2001, ftp://ftp.cordis.lu/pub/ist/docs/digicult/lund-report.pdf. For further information on the development of the Lund Principles see: S Ross (Rapporteur), 2001, *Report of the First Meeting of the National Representatives Group*, Brussels 11 December 2001 ftp://ftp.cordis.lu/pub/ist/docs/digicult/nrg-1st-meeting-report.doc; S Ross (Rapporteur), 2001, *Report of an Expert Meeting on Coordination of National Digitisation Policies & Programmes*, Brussels, 17 July 2001, ftp://ftp.cordis.lu/pub/ist/docs/digicult/brussels_report_17_july_2001.doc ; S Ross (Rapporteur), 2000, *Report of an Informal meeting on European Digital Content for Global Networks and Co-ordinating Mechanisms*, European Commission, Luxembourg, 15 - 16 November 2000, ftp://ftp.cordis.lu/pub/ist/docs/digicult/lund_dossier.pdf (pages 26-38 or 22-34).

The problems associated with managing digital materials raised by the tremendous growth in numbers of institutions digitising analogue collections and in the increasing production by society of borne digital materials make issues surrounding digital libraries and digital curation[V] a central part of the work of cultural and scientific heritage institutions. The DELOS Network of Excellence, http://www.delos.info, funded by the European Commission under the Sixth Framework is attempting to address a wide range of issues surrounding the development of digital libraries from architectures to interface design and evaluation. This is an area of real action within the archival and library communities and it is an area of research within information and computing science that is attracting research work. Alongside digital libraries the issues surrounding digital curation are demanding more attention from libraries, archivists and researchers. There are many good sources of information about on going work, such as ERPANET (http://www.erpanet.org), the Digital Curation Centre (http://www.dcc.ac.uk) and PADI (http://www.nla.gov.au/padi/), but there is still a shortage of off-the-shelf technologies that can be rolled into service to support digital curation initiatives at cultural and scientific heritage institutions. The challenges surrounding management of these digital materials is closely linked to issues surrounding access to them and their exploitation.

As institutions working with cultural and scientific heritage materials increasingly make their analogue holdings available in digital form and collect borne-digital materials the debate surrounding public access to these public sector resources will take focus. The Lund Principles, adopted by the EU Member States in 2001, stressed that access to publicly created and owned digital resources by the citizen should be free of charge at point of use. Within the European Union the public sector information directive (EU Directive 2003/98/EC)[VI] published on the 31st of December 2003 sets out parameters governing public access to information produced by public institutions. The Directive aims to promote access and economic exploitation of this wealth of resources. Unfortunately the directive provides exemptions for 'documents held by cultural establishments, such as museums, libraries, archives, orchestras, operas, ballets and theatres.' Perhaps a review of this directive, which must happen before the close of 2008, could consider whether or not it would make economic sense to ensure open and free access to the information resources (e.g., databases and digitised materials) held by heritage institutions.[VII]

V We use digital curation in preference to digital preservation because it is a much richer term and focuses on access, preservation, conservation and management of digital materials

VI http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_345/l_34520031231en00900096.pdf

VII Studies worthy of mention include PIRA International, 2000, *Commercial Exploitation of Europe's Public Sector Information. Final Report*, European Commission, Directorate General for the Information Society, ftp://ftp.cordis.lu/pub/econtent/docs/commercial_final_report.pdf and Peter Weiss, 2002, Borders in Cyberspace: Conflicting Public Sector Information Policies and their Economic Impacts, Washington DC, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, http://www.weather.gov/sp/Borders_report.pdf . Nearly a decade ago Kathleen Eisenbeis (1995) reported in *Privatizing Government Information: The Effects of Policy on Access to Landsat Satellite Data* (Metuchen, N.J.: The Scarecrow Press, Inc) of the risks associated with restricting public access to public sector information resources.

Open Source Software and Standards

Executive Summary

The *Open Source* software movement represents and characterises a thirty-year-old software development philosophy and ideology. In recent years, the Open Source ethos has come to fruition within a range of commercial, public and heritage environments. Core beliefs in the principle of free software availability, and of a community-based approach to software development have increasingly established Free and Open Source software (often abbreviated to OSS, or FOSS) within the mainstream, where its many associated applications now reside as realistic and competitive alternatives to proprietary commercial software produced according to a more traditional 'behind closed doors' development model.

With its near ubiquity within a range of institutions, the presence and extent of use of Open Source are projected to increase in the short to mid term. By becoming educated about alternatives to conventional software design and licensing methodologies, institutions will become empowered to choose the appropriate tools to achieve their intended outcomes. This will limit the dangers inherently posed for heritage institutions relying upon specific commercial proprietary software solutions, most notably surrendering IT infrastructure control to the technology vendors – often at significant costs in financial and functionality terms.

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Open Source technologies are important to the heritage sector for exactly the same reason that they are relevant to anyone else concerned that computing investment of time and money reaps the maximum rewards. These technologies are no longer the marginalised preserve of the 'geek' hobbyist. Instead, they offer some of the most proven, reliable and long-term solutions available. Knowledge leads to choice, and choice leads to value: a wide range of quantitative evidence exists to suggest that Open Source offers excellent value in terms of total cost of ownership (TCO). Open Source is closely related to the concept of open standards, which seeks to remove the mystery from information storage and use. These principles aim to excise much of the opaqueness that threatens and disrupts digital preservation, limits and curtails access to long-term stored documents, and hampers the straightforward exchange and interchange of digital content. An understanding of the structures that underlie the software we use – as well as the legal rights to recreate, modify and redistribute these structures – is a great facilitator to everyone: from desktop users looking for an application specifically tailored to their needs, to large scale memory institutions that need to ensure that the software format they select to encode their digital archive will not become obsolete, unsupported and impenetrable within a few years' time. The main beneficiary is the institution or individual user, and this is the way it should always be.

The IT industry is currently engaged in a state of transition. Traditionally such periods are due to the development of new technologies but, in this instance, the revolution is instead in terms of methodology. That Open Source offers a range of advantages over proprietary software products is not undisputed, but sufficient persuasive arguments exist to make it, at the very least, worthy of consideration by any IT infrastructure decision maker.

The case studies featured in this Briefing cover a range of OSS applications, from the large-scale governmental rollout of *LinEx* to the subject-specific deployments of *Gamer*a. The scenarios that follow detail the processes and concerns involved in making the institutional changeover from proprietary to Open Source software, as well as providing examples of the situations likely to be encountered in the development of an Open Source application.

An Introduction to Open Source and Free Software.

Background

The traditional, commercial proprietary software development model, the model that until fairly recently was responsible for the vast majority of software in widespread use, has a number of key characteristics. When a software application is initially created, it is usually written in a programming language, a human readable syntax that broadly corresponds to the way in which a computer understands and processes information. However, for a computer to make sense of a program it has to be offered in a much 'lower level' format - ultimately the 1s and 0s of binary. In order to transform a program from human-readable form to binary, the code must go through a process called 'compiling'. The original program code, called the 'source code' is passed through an intermediate program and translated into computer readable syntax, which to human eyes bears very little relation to the original. Under the traditional proprietary software development model, developers will typically perform the compiling process and then distribute the binary results to customers, who can run the program and enjoy its benefits without any sense of how the program operates, and crucially without any means of finding this out. Users are also unable to change the way the program runs, other than by using the program's inbuilt configuration tools. An analogy can be drawn with the baking of a cake. If one regards the recipe and process of mixing all the ingredients together as the 'source code', close comparisons can then be drawn between the baking process and the compiling process. By tasting the resultant cake, it may be possible to guess what ingredients are included but it is not possible to add any additional ingredients or to recreate the cake without clear details of the initial recipe.

Proprietary software companies therefore find themselves in a commercially strong position. By limiting customer access to the binary files they control the functionality of their applications, and can impose limitations based on their own distribution or upgrade policies and plans. If problems occur with software, new features are sought or versions are required for alternative hardware/software platforms, they must all be negotiated with the software vendor. The customer is likewise powerless to fix bugs that may be identified within the system, since these (like all changes) must be addressed at source code level. Because the source code access is typically limited to a very small group of developers, changes inevitably take time to implement, and the addition of specialist functionality may be overlooked or considered not commercially viable.

Definitions

The Open Source and Free Software movements share a common goal, but differ subtly in emphasis. While both oppose proprietary hidden-source software development and distribution, their motivations for doing so are contrasting. The distinction between Free Software and Open Source software is interesting for a number of reasons, and serves to highlight a range of advantages offered by their shared goal. Both movements believe in the same general ethos: that all software should be made universally available in its entirety, with everyone afforded the opportunity to examine, change and redistribute it.

Free Software

The Free Software movement, spearheaded by the Free Software Foundation (FSF) and characterised by the writings of Richard Stallman, has at its core a predominantly political, social, and moral agenda.[1] From its origins in the late 1970s and early 1980s, the Free Software school grew out of frustration with the barriers imposed by the secretive nature and non-disclosure agreements of proprietary software. Uncompromising in its philosophy, the movement argues that a number of fundamental human freedoms depend on the ability to access software without obstruction. The definition of Free Software is displayed prominently on the FSF Web pages, and can be broken down into four parts, each relating to one of the four essential freedoms:[2]

1. The freedom to run a program, for any purpose;
2. The freedom to study how a program works, and adapt it to individual needs, implying access to the underlying source code;
3. The freedom to redistribute copies;
4. The freedom to improve the program and release improvements to the public so that the whole community benefits, again implying source code access.

These simple definitions offer a comprehensive insight into the priorities and motiva-

1 http://www.fsf.org; http://www.stallman.org
2 "The Free Software Definition," http://www.fsf.org/philosophy/free-sw.html

tions of the Free Software movement. In the absence of a suitably unambiguous word in the English language, the classic definition of free is "free as in free speech, not as in free beer." While there is no stipulation that free software should be made available without cost, it should be possible to *redistribute* bought software at no cost if it is to qualify. Stallman also identifies three levels of 'material harm' caused by non-free software. He argues that (i) fewer people will use (or be able to use) the program, (ii) that none of the users will be able to adapt or fix the program, and (iii) that no other developers can learn anything from the program, or base new work on it.[3] With this he refutes the traditional legal ownership arguments for proprietary software. He claims that traditional property law concepts are irrelevant since they relate to the problems caused by *taking away someone else's property*, not simply *making a copy*. Programs are not consumed in the same way as other types of property, and should not be subject to the same values. Although legal controls exist to limit the use of a wide range of software, Stallman views these with contempt, choosing to differentiate between what is legal and what is morally appropriate. Central to his philosophy is the idea that human development and progress should be able to benefit all society, not just those in possession of the appropriate legal instruments. The Free Software movement is committed to a culture whereby users can benefit from the time already spent by others solving problems, negating the need to 'reinvent the wheel' themselves. The free availability of software is regarded as being of fundamental importance, and worthy of pursuit even at the expense of other aims. In a recent email conversation with Stallman, the question was posed about what to do when the teaching of music students required the use of proprietary software tools with no free software equivalents. Stallman explained that "as an ethical issue… the goal of freedom is more important than specific practical computer goals. What can be done with free software, I do; the rest, I don't." He continued to argue that "[w]hile music is a good thing, [it] is not a matter of life and death. The desire to explore music does not seem to come even close to justifying use of non-free software."[4]

Open Source

Many have attributed the uncompromising idealism of Stallman and the rest of the Free Software movement to one of the reasons for Free Software remaining somewhat marginalised within the computing community. The zeal (or zealousness) displayed by the heavily-bearded Stallman has at times left users somewhat ill at ease, despite the Free Software movement's impressive track record in terms of software development. In the mid 1990s a new movement evolved in reaction to this, seeking to characterise and promote the more 'sellable' aspects of Free Software, while giving much less emphasis to the social, moral and political arguments favoured, and regarded as absolutely fundamental to Stallman and the FSF. This movement was dubbed 'Open Source,' now represented by the Open Source Initiative (OSI) with the programmer and writer Eric S. Raymond at its helm.[5] A quote from the OSI Web site illustrates the shift in emphasis from that of the Free Software Community: "We think the economic self-interest arguments for Open Source are strong enough that nobody needs to go on any moral crusades about it."[6]

3 "Why Software Should be Free" http://www.fsf.org/philosophy/shouldbefree.html
4 Email conversation between Richard Stallman and Andrew McHugh of HATII, University of Glasgow, May 29th 2004.
5 http://www.opensource.org; http://www.catb.org/~esr/
6 http://www.opensource.org/advocacy/faq.php

Raymond and the OSI realise that there are more persuasive advantages inherent in the use and development of Free Software than in the less quantifiable advantages based in concepts of morality. The OSI's foremost argument is that the unique development model underpinning Free Software leads to *better quality software* than that developed behind closed doors by the paid employees of commercial companies. Inevitably, Stallman and the FSF also have a vested interest in the quality of their software. Without a suitably robust and functionally-rich suite of free applications, the Free Software movement would have no choice but to make concessions to the proprietary software world in order to exist at all. It was this reasoning that led to the development of the *GNU/Linux* operating system, the first major success for Free Software.[7] *GNU/Linux* was a crucial step, since without a platform on which to run free software, the case in favour would begin to look rather thin. There is a sense that the Free Software movement regards the success and quality of the software it develops and endorses primarily as a facilitator to the overarching goal of political change. Popularity and widespread use of good software is a far lower priority to the Free Software Foundation than ensuring that software remains free. "It is no use driving faster," writes Stallman, "if you can't stay on the road."[8]

The Open Source Initiative publishes on its Web site a definition of software that qualifies as Open Source.[9] This definition is closely related to that of the Free Software Foundation, although some distance has been drawn by subsequent comments and issues relating to the licensing schemes endorsed by each movement. Notably, the Open Source definition is not structured in terms of individual human freedoms, and is closer to the kind of legal documents that will be familiar to users of traditional commercial software products. Among the ten individual requirements are: that Open Source software must be freely distributed; that source code must be available along with any compiled binaries; and that modifications and derived works must be permitted and re-distributable under the same license[10] as the original software.[11]

Software Licenses

In order to outline the usage rights associated with a particular software release, to maintain its legal status and protect it from abuse, it is standard practice to distribute a license agreement alongside any program. This is essentially a legal account of the terms under which the application is offered and incorporates details of how it can be used, and by whom. The Free Software Foundation considers the merits of a particular software license based on a number of criteria. These are: (i) whether it qualifies as a Free Software license; (ii) whether it is a *Copyleft* license; (iii) compatibility with other licenses; and (iv) whether it causes any practical problems.

To establish whether a license qualifies as Free Software, it becomes necessary to compare the license's terms with the Free Software Definition to ensure that no conflicts

7 http://www.linux.org/
8 http://www.fsf.org/gnu/why-gnu-linux.html
9 http://www.opensource.org/docs/definition.php
10 For convenience, the American English spelling of the noun "license" is used throughout.
11 Needless to say, these requirements have a great deal in common with those outlined for Free Software. However, the Free Software Foundation generally places higher ethical demands on software licenses, so while most, if not all Free Software approved licenses will be Open Source, the opposite is not necessarily true.

exist. Conformity will be possible only if the license permits free access, modifications and redistribution.

Copyleft is a concept of the Free Software Foundation and serves as an alternative to traditional copyright restrictions. The coining of the term came in the light of concerns that without some kind of protection, Free Software could be taken by proprietary software developers, changed and then redistributed under a proprietary non-free software license. The *Copyleft* requirement makes it impossible to "strip off the freedom" in this fashion. *Copyleft* says that anyone who redistributes the software, with or without changes, must pass along the freedom to further copy and change it. Some opponents of Free Software have dubbed this "the viral clause" because it means that any new software that incorporates existing *Copyleft* code automatically inherits the same license. Thus, the code and the freedoms of the license become legally inseparable. According to Stallman, "the idea of *Copyleft* is that we should fight fire with fire."[12] Elsewhere, Stallman explains the naming of the concept:

> Proprietary software developers use copyright to take away the users' freedom; we use copyright to guarantee their freedom. That's why we reverse the name, changing 'copyright' into 'Copyleft.'[13]

In order to combine two programs (or substantial parts of them) into a larger work, one must have permission to use both programs in this way. If the two programs' licenses permit this, they are compatible. If there is no way to satisfy both licenses at once they are incompatible, and for some licenses the nature of the combination may affect their compatibility: the licenses may allow the linking of two modules, but not the merging of their source code into a single module. However, a program can still qualify as Free Software even if its license is not compatible with others.

The potential for distribution problems must also be assessed for each license, although this will not affect a license's free status if the requirements of the Free Software Definition are met. The most common software license under which Free and Open Source software is distributed is called the *GNU General Public License* (GPL).[14] Originally conceived to describe the legal status of the GNU operating system, this has become the generic standard Free Software license. It is a *Copyleft* license, and establishes and seeks to protect the freedom of its associated software quite strictly. However, a number of alternative 'off-the-shelf' licenses are now available for developers and distributors to utilise, and these can be Free, or Open Source, or both.[15] The terms of one license may be more appropriate than those of another, depending on the nature of the particular application or project. For instance, if a developer wishes his library code to be more widely used within other applications he may choose to distribute it under the Lesser General Public License, which has no Copyleft effects for linked files. This would mean that more developers would be prepared to use it (including proprietary software developers), bugs would be identified and fixed more quickly, and ultimately the code would be improved. If no license suits the intentions of a particular developer or project, it is possible to define a new license and submit it to the FSF and/or OSI for endorsement.[16]

12 Richard Stallman, "The X Window's Trap": http://www.gnu.org/philosophy/x.html
13 http://www.gnu.org/copyleft/copyleft.html
14 GNU is a recursive acronym for 'GNU's Not Unix.'
15 See http://www.opensource.org/licenses and http://www.fsf.org/licenses for details of approved licenses.
16 See the Software Release Practice How-To at http://www.tldp.org/HOWTO/Software-Release-Practice-HOWTO/index.html for details of the importance of choosing the right license.

The Allure of Open Source for Developers and Users

Quite apart from the moral/ethical arguments in favour of Free and Open Source software, most readers will expect some insights into their more pragmatic merits before being tempted to use it, or to develop applications under such terms. These tend to be the issues emphasised by the Open Source community in the promotion and justification of OS software and, as such, will be our primary focus for the remainder of this report. There are several persuasive arguments in favour of using Open Source software, and of releasing under an Open Source license. Many of these are generic, and are equally applicable to computer users in any field, activity or industry, but there are additional arguments likely to be of particular interest to the Cultural Heritage community given its particular range of goals and responsibilities.[17]

Genesis and Development

In practice, an Open Source software project can originate and proceed in a number of ways. The first stage is for someone to identify a problem or a 'software void,' and decide that it is worthwhile to address the issue by developing a new application. In his landmark book about Open Source philosophy and practice, *The Cathedral and the Bazaar*, Eric Raymond describes how "every good work of software starts by scratching a developer's personal itch."[18] Personal motivation is an intrinsically important factor for any Open Source developer. Since many projects are carried out primarily in programmers' spare time, it is vital that they have a genuine interest in the success of their work. This has been cited as one of the strengths of Open Source software compared with a more traditional, commercially driven model. It is likely that the personal associations that an Open Source developer feels with the program he or she is writing will lead to a high quality of work. This may be less of a priority for salaried programmers writing software that they have no real interest in using. Conversely, of course, it can be argued that due to the direct financial remuneration associating the salaried programmer with his company's application he will in fact feel a greater sense of responsibility and of personal accountability. Raymond argues that the Open Source developer's additional motivation – i.e. establishing kudos and reputation within the community – is stronger than money, and that the personal satisfaction and pleasure obtained from developing programs are essential ingredients in the success of Open Source. The goal of many Open Source developers is to play a prominent role in the development of a 'killer app' – an application that by virtue of its comprehensive functionality, reliability and usefulness renders all competitors obsolete.

It is often suggested that a commercial product will be developed according to a more rigorous timetable than its Open Source equivalent, and that turnover of new versions will be more frequent and regular. In fact, the development and release times for Open Source software tend to be much quicker than those of commercial software. In any case, over ambitious release timetables have often been to blame for the release of a variety of

17 A succinct introduction to Open Source software and its benefits can be found in "Open Source and Free Software Solutions: Reliable standardised, free" in *DigiCULT.Info*, Issue 5, October 2003, pp. 36 http://www.digicult.info/pages/newsletter.php

18 http://www.catb.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/ar01s02.html

buggy, unfinished proprietary software products, which subsequently have to be fixed with software patches.[19]

Another common argument is that since Open Source projects tend to be initiated on the whim of their developers, there can be little way to ensure that the highest priority software applications are developed. In practice, this is not really the case. Thanks to the depth and breadth of the Open Source software community, the value of particularly significant or successful programs is soon identified, and people immediately wish to become involved in their development for the potential prominence that this will win them. In many instances, a number of individual software projects will start work in similar areas before a leader emerges, and at this stage contributions will tend to focus here. Competition in the software business is useful for business, but does not necessarily lead to the development of the best software. Since the Open Source model pools expertise, and does not set programmers the task of usurping one another, in software terms it can very quickly achieve a great deal.

A more legitimate criticism of Open Source is that developers are attracted only to the interesting, 'sexy' programming projects, which allow them to exercise their imaginations, and not to the more mundane, equally vital programs. Programmers also tend to be uninterested in producing documentation to accompany their work, which from a user perspective is often as important at the program itself. Fortunately, the Open Source model offers opportunities for collaborators to assist by providing documentation. This is quite common for those who wish to be involved but who lack the programming expertise to contribute code.

Community and Collaboration

The issue of community and collaboration is central to the Open Source development model. Once a particular project is started, the worldwide Open Source community will perform one or more roles in the development of the application. The most commonly provided service is consultancy, where advice is offered, suggestions made, and ideas debated via fora, newsgroups, wikis, blogs, and chat rooms. Collaboration is undertaken at a more practical level too, and much of the success of Open Source can be attributed to this. At the simplest level, this involves code debugging, program testing, and identifying and fixing flaws or shortcomings. With the source code readily available, these changes can be implemented by remote developers. Technologies like the Concurrent Version System (CVS) allow a wide community of users to access and update the very latest version of a program's source code. Input can extend beyond debugging, and can involve steering the fundamental functionality offered by a particular application. The level of management that a project originator imposes on a project and the direction it takes will vary, although practice has shown that many successful projects, such as the *Linux* operating system, have been successful with little management 'muscle-flexing.' Illustrating the style of development he describes as 'the Bazaar,' Eric Raymond describes how "the Linux community seemed to resemble a great babbling bazaar of differing agendas and approaches … out of which a coherent and stable system could seemingly emerge only by a succession of miracles."[20] Some articles refute Raymond's claim that Open Source projects manage themselves, instead citing a strong individual presence in each project

19 A software patch is a small set of programming code that repairs a problem with a particular application.
20 http://www.catb.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/

(*Linux* creator *Linux* Torvalds and Wikipedia founder Jimmy Wales are two good examples). However, from a user's perspective, the key consideration is that the system works, not necessarily why or how it works.

Once an Open Source application has become established, contributions tend to gather greater pace. A wider user-base represents more potential contributors, and this can be administered in debugging, documentation, and other general feedback.

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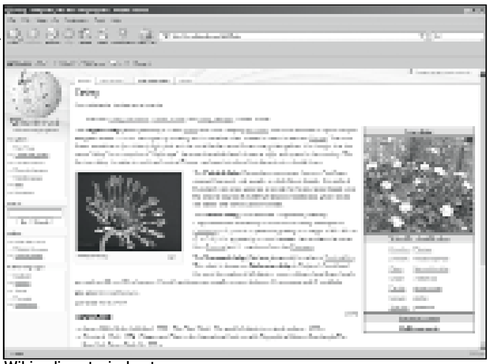


Wikipedia: a typical entry

Cost Issues

The argument most frequently presented in favour of Open Source software is that it is available without cost. This is not necessarily true, and provides a first impression of Open Source that perhaps does not do it justice. Certainly the vast majority of Open Source code is distributed without cost from developers, and the licensing restrictions mean that even if a single user is charged for a program it can be subsequently redistributed to an unlimited number of people at no cost at all. However, people tend to be sceptical of anything for which they do not have to pay. The mention of "free software" may conjure thoughts of the freeware or shareware applications prevalent across the Internet, which frequently offer limited or broken functionality and are often accompanied by advertisments or unwelcome malware or spyware. Users may also be suspicious of hidden catches: it is quite common for proprietary software developers to distribute "free" evaluation software, with some crucial functionality deactivated until a license is purchased.

These examples all deal with proprietary applications, which share none of the real advantages of Open Source software. By considering cost aspects alone it is very difficult to express the value of Open Source technologies effectively. No self-respecting IT decision maker would choose to install and use a new application simply because it was cheap, or free of charge. It is far more likely that he would reject it, with the inference that it must have less functionality than its commercially released equivalent. Instead of dwelling on the cost (or lack thereof) it is important to emphasise the fundamental qualities of Open Source software, and the many benefits that are a direct result of the unique development model at its foundation. Once these issues have been explored, and one becomes clearer about how and why Open Source works so well, the *gratis* price tag begins to look more like an unexpected but welcome bonus, and less like a potential source of doubt.

User Benefits

From a user's point of view, the success of any individual software application will be based on a number of individual factors. These include: depth of functionality; number of bugs and the speed with which they can be fixed; availability of quality documentation and support; level of in-built security; and monetary cost. The overall priority weighting of each will vary from place to place, but all will usually require consideration. A more comprehensive quantitative account of Open Source's success in some of these areas is given below, but it is also useful to consider these issues from a more theoretical perspective.

The overall depth of functionality offered by a particular program is the most immediate and obvious indicator of its usefulness. It would be untrue to say that a program bursting with features would always be successful (it could have a poorly-designed user interface), but one can usually tell quite quickly if an application lacks sufficient power to achieve what is needed. Since Open Source involves potential users at every stage of the development process, the functionality requirements and expectations that users have can be identified and implemented effectively. Unique or marginalised functionality can be incorporated into existing applications straightforwardly, thanks to the availability of source code. Features that would not be worthwhile for a commercial company to implement due to the lack of overall user demand can be introduced, and new projects can be started when it seems that a particular software void is unlikely to be filled. The Open Source model empowers users to either develop their own specifically required applications or to add their own functionality to existing ones. The commercial software world cannot compete with this flexibility. At best, it will probably charge a premium fee to add a particular feature at the request of an individual client or, more likely, assure the customer that the functionality will be integrated when they pay to upgrade to the next version of the software.

Development and Refinement

The identification and correction of bugs from programs is another strength of the Open Source development model. All but the most straightforward of software programs will contain bugs: they are a regrettable, but inevitable part of software development. With traditional software development, it is common for a team of programmers to complete an application and, through a period of formative and summative debugging, identify and fix errors. However, this kind of process will generally yield untidy results, often known as *kludges*. The company could spend a great deal of time identifying and fixing problems within the code, but this is not desirable from its point of view since it is keen to get the product on the shelves and generating income. Users will then start finding flaws, but without access to source code it is impossible to fix these personally; the only recourse is to notify the software house responsible. When this happens, there can be a number of potential outcomes. If a bug is sufficiently serious then the company will probably issue a software patch to repair the flaw. This results in a bottleneck effect however, and the development of this and other applications can be adversely affected as time spent repairing bugs from old versions is not invested in new developments. Additionally, since the company relies on bug reports from users who have no access to source code it can be difficult to trace bugs, making the process more time-consuming while the potential programming ability of the application's users goes unexploited. There is usually nothing but goodwill to guarantee that companies make these corrections available free of charge, and it has been known for commercial software companies to charge users for corrections to buggy software. Alternatively, the company can refuse to address the flaw at all, leaving users with no option but to learn to live with the deficiencies in the applications.

The Open Source community's approach to debugging is more effective. Relying on the philosophy of releasing software 'early and often,' Open Source projects will receive invaluable end-user bug reports before a program is close to the level of maturity that a commercial company would deem acceptable for release. With access to source code, collaborators can fix problems themselves, or offer detailed accounts in programming terms where bugs exist (and under what circumstances), which can then be addressed by someone else. "Treating your users as co-developers is your least-hassle route to rapid code improvement and effective debugging," writes Eric Raymond, his mantra: "Given enough eyeballs, all bugs are shallow." Lack of effective documentation and support structures have traditionally formed the basis for a great deal of the criticism that is levelled at Open Source, particularly from corporate customers who have more exacting requirements, need assurances that someone can be held accountable for problems, and who will bear the brunt of responsibility should things go wrong. In fact, these are two separate issues. Open Source projects are becoming increasingly well documented, and the rapid growth and mainstream proliferation of Open Source has led to the generation and prioritisation of good quality documentation.

Support Issues

Support for Open Source products has traditionally taken a number of different forms, most straightforwardly categorised into informal and formal support structures. Informal support has always been available, and is generally very useful. This incorporates Web fora, FAQ postings and "how-to" guides, which are often wide-ranging and comprehensive in their scope thanks to the large online community of users and developers. The enthusiasm that pervades the Open Source movement in general is evidenced in these environments where help is freely offered to facilitate software use. More formal support structures are less well established, existing mainly for corporate users and tailor-made to reflect this. Large-scale *Linux* distribution companies such as **Red Hat** and **Mandrake** offer the kinds of products and services with which enterprise customers are familiar and expect from software vendors, such as service level agreements (SLAs), comprehensive support structures, and training programmes.[21]

An argument often raised by those opposed to Open Source is that if something goes wrong with the software there is no one to direct the blame towards. This may be true, but the majority of proprietary licenses will include terms absolving responsibility for problems caused by flaws or shortcomings in software. No one has successfully sued **Microsoft** for recompense for the downtime caused by viruses that exploit security loopholes in their *Windows* operating system.[22] In fact, litigation between proprietary

21 http://www.redhat.com; http://www.mandrakelinux.com/

22 In fact, Microsoft's Windows XP license includes the clause "In no event shall Microsoft…be liable for any…damages whatsoever…even in the event of fault…(including negligence)." See http://seattlepi.nwsource.com/business/139286_msftliability12.html for more details.

software companies and users is much more likely to be undertaken in the opposite direction, as companies seek to control user activity through frequently restrictive and demanding licenses and usage agreements. By not owning an appropriate license, individuals and businesses can expose themselves to potentially huge fines, and even prison sentences. This places a further burden on the user to administer licensing details and ensure that the correct infrastructure is in place so no infringements can take place. Open Source has no such problems, and only steps taken to *limit* free access to Open Source software are likely to fall foul of licensing agreements.

The Internet remains a dangerous place, with the potential for virus infection, denial of service attacks and interception of personal details causing many users concern. Security is inevitably a high priority for software developers and users alike. It is often argued that by making source code available it will be easier for malicious individuals to identify and exploit security vulnerabilities in Open Source software. Once again, this represents a false argument, typical of the "Fear, Uncertainty and Doubt" strategy frequently employed by the proprietary software world to dissuade potential users from moving to Open Source alternatives. In fact, the sense of 'security through obscurity' promoted by proprietary software companies is dangerous: not only does it create a false sense of security, but it also limits opportunities for identifying existing loopholes. Malicious 'crackers' are generally motivated and determined, and will ultimately uncover whatever vulnerabilities exist whether code is freely available or not. The advantage of opening the source is that those who are interested in finding problems to fix (rather than to exploit) can do so as straightforwardly as possible. Additionally, once a vulnerability is identified it is much more straightforward in an Open Source environment to apply a patch, and to be sure that it is reliable and trustworthy. And while this should not lead to complacency, Open Source users are less likely to find themselves the target of malicious attacks than those using proprietary tools, since a great number of destructive code is motivated by distrust and resentment of large corporations.

Financial

The final consideration of those hinted at above is monetary cost, and there can be little doubt that in terms of software acquisition, Open Source represents far better value for money than proprietary software tools. However, there are other costs involved in any software policy including associated hardware costs, retraining, technical support, migration of existing data and legal costs. These are more effectively described in terms of Total Cost of Ownership (TCO), which is explored in some detail below.

Conclusion

While Open Source has inherent advantages for users, there are reasons why a developer would choose to make an application Open Source. From a practical point of view, a great deal of software is released under an Open Source license because it is the only way legally to integrate existing Free Software code or libraries that are covered by some kind of Copyleft clause. Because of the vast range of well-written software that is currently available under the GPL (for instance) it may be a more attractive prospect to build on the work of others than start from scratch, replicating functionality that already exists and is freely available. Developers who choose an Open Source license may also be keen to consult the Internet-based developer community in order to test and improve its applications, absorbing the advantages detailed above. This is particularly useful for solo developers, and small groups for whom outside intervention, assistance and feedback would be beneficial.

A further incentive could be the presentation of work to a wider audience. A selection of popular Web sites exists to promote and distribute Open Source software materials (e.g. *SourceForge*). For applications that work well, success and prominence usually follow with word spreading around the community.[23] Umbrella resources like the **Open Source Developers Network** offer a platform for shared ideas and knowledge interchange, and at the same time providing mechanisms for the promotion and distribution of Open Source applications.[24]

Openness: Friend of the Future

Open Source and Open Standards

The philosophies underpinning Open Source software have close associations with the concepts of Open Standards that are vital for successful exchange, reuse and preservation of documents and data. Open Standards are those that, by virtue of their transparency and accepted nature, offer protection against obsolescence and inaccessibility. Technologist Bruce Perens suggests a definition of the Principles and Practices surrounding Open Standards, containing detailed insights into what significant details elevate a simple specification to the status of Open Standard.[25] These principles describe the freedom to view and implement the standard, creating a fair, competitive market for its implementation, and preventing customers from being 'locked in' to a particular vendor or group. In addition, there should be no associated royalty or fee and no favouring of one implementer over another. Finally, implementations of Open Standards may be extended or offered in subset form, although controls must exist to prevent dominant vendors from implementing the standard with extensions that are incompatible with other systems. Close parallels can be drawn between these points and the Open Source definition, particularly in terms of their emphasis on freeness and the unencumbered total access that they implicitly offer. Examples of Open Standards for file formats include XML, HTML and **Adobe**'s PDF format. These represent fairly 'safe bets' for storing content for future retrieval since all are understood, documented and published universally. There are no associated licensing costs and the use and distribution of these formats is not chargeable.

By relying on a combination of Open Source applications and Open Standards, it is possible to avoid a number of future headaches that often accompany the use of proprietary technologies. Commercial software companies understand that if they can propagate their own particular file formats widely enough, people will soon become reliant upon them. The most obvious example is **Microsoft**'s *Office* suite, which uses the core file formats .doc, .xls, .mdb and .ppt to encode word processed documents, spreadsheets, database files and slideshow presentations. None of these are Open Standards, hence it is

23 http://sourceforge.net/
24 http://www.osdn.com
25 http://perens.com/OpenStandards/Definition.html

impossible to gain a thorough understanding of how they work, and there is no way to read and write to these formats confidently with programs other than **Microsoft**'s own.[26] In his article 'Who Gave **Microsoft** Control of Your IT Costs? You Did,' David Berlind pulls no punches: "Putting the vendor in control of your IT costs is not a good position to be in. Unfortunately, that's where a lot of us are."[27] The combination of proprietary software and proprietary standards puts the software distributor in an unhealthily powerful position, and exposes the customer to the cost of 'essential' upgrades and even greater problems should the technology be discontinued or the developer become insolvent. Every time that a user records data in a closed format it tightens the grip held by its proprietary developer. The chain becomes increasingly more difficult and more expensive to break away from. It should be clear that when preservation issues and future content access are considered, the problem is only exacerbated.

Preservation Through Transparency

The Cultural Heritage sector is no stranger to costly projects that have failed because of technological choices that were overly proprietary or marginalised. The **BBC**'s *Domesday* project is a frequently cited example.[28] In 1986, to celebrate the 900th anniversary of the Domesday Book, a project was undertaken to incorporate a diverse range of materials contributed by UK schoolchildren within a multimedia resource. Unfortunately, the project's technological choices were made with little foresight. For storage media, the project team chose to use **Philips'** proprietary *LaserVision LVROM* disc, which could only be played on the associated LVROM player. The multimedia application itself was written in a language called BCPL, a precursor to C which ran on the **BBC** *Model B* platform. Regrettably the discs soon became obsolete and, less than twenty years later, very few players or discs remain. Only the sustained efforts of the *CAMiLEON* project to rescue the application and implement an emulation strategy have ensured that future generations can access this valuable resource.[29]

Of course, Domesday need not have come up against such problems if a more future-conscious series of decisions had been made at its conception. The biggest single problem for the project (and for digital preservation generally) is its inability to ensure that at an unknown time in the future users will be able to access stored materials regardless of format.[30] An analogy with the original Domesday Book is made on the CAMiLEON project Web site. If the Latin language in which the original Domesday Book is written somehow became completely incomprehensible, accessing the information it holds would be impossible.[31] The issue of preservation is not limited to maintaining the physical materials themselves; it is also necessary to ensure that a method of understanding them continues to exist in perpetuity. By using open, standardised formats, one can gen-

26 Numerous projects, such as OpenOffice.org have tried to remedy this, with substantial success. See also summary of CAMiLEON working papers in: The *DigiCULT Report Full Report* "Technological Landscapes for tomorrow's cultural economy: Unlocking the value of cultural heritage", (January 2002), pp.212. Available online at http://www.digicult.info/pages/report.php,.

27 http://techupdate.zdnet.com/techupdate/stories/main/0,14179,2875958,00.html

28 http://www.atsf.co.uk/dottext/domesday.html

29 http://www.si.umich.edu/CAMILEON/domesday/domesday.html. See *DigiCULT.Info 4* for more on CAMiLEON's work with Domesday. http://www.digicult.info/pages/newsletter.php

30 An Open Source tool which 'normalises' file formats for preservation is described in "XENA: Electronic Normalising Tool" in *DigiCULT.Info*, Issue 7, April 2004 http://www.digicult.info/pages/newsletter.php

31 http://www.si.umich.edu/CAMILEON/domesday/faq.html

erally limit the problems that will be caused by the passage of time. If the Domesday project had used a valid XML structure to describe and encode its multimedia components, together with open formats for incorporated sound and video, a clear understanding of the data structures could be established at any time in the future, with no need for guesswork or painstaking reverse engineering procedures. Additionally, if the application that coordinated these materials was written in a standardised programming language it, too, could continue to be understood. However, this would only remain so if the application's source code was made open and freely accessible.

New digital hardware will inevitably develop, and it is likely that the machines we use twenty years from now will operate quite differently from those we use today. But the hardware level is just one of three potential areas where preservation problems can occur. Assuming that data are recorded in an open file format, and that the programs that read, access and write to these formats are Open Source, any hardware-related preservation problems can be quickly overcome. The knowledge conferred by the use of Open Source applications and Open Standard Formats empowers future users and will allow any resource to be straightforwardly ported to a future hardware configuration with minimal effort. In a closed source environment, future preservationists would be faced with the unpleasant task of reverse engineering software to run on every new platform, or maintaining the old hardware upon which the resources will operate. License agreements associated with OSS make it easier to take preservation measures without fear of violating the intellectual property claims of the original developers. As doctoral student Cal Lee of the **University of Michigan** points out, "Most vendors have very little interest in continuing to support their older software indefinitely, though they do have a tendency to legally challenge anyone else who attempts to do so."[32]

Where is Open Source Used?

Introduction

From its origins in laboratories, technology centres and bedrooms, Open Source has exploded in popularity over the last few years, and now performs a key role in the IT policy and infrastructure of many organisations, institutions and companies. With so many arguments in its favour, it is inevitable that justifications for taking an Open Source approach tend to vary across the sectors in which it enjoys such exposure. Many are attracted to the traditional stability and reliability of the software, others to its straightforward integration with heterogeneous system environments, and others to the empowering openness intrinsic to Open Source. Many more may be convinced by the clear financial savings that can be made in using these technologies.

Government and Public Sector

The increasing success of Open Source in the public and government sector has been one of the most significant developments of recent times in terms of technology take-up. Public sparring between proprietary software companies and the Open Source movement for lucrative governmental IT contracts emphasises the significance of this market,

32 http://www-personal.si.umich.edu/~calz/oss_preservation.htm

particularly for the subsequent dissemination of technologies throughout the public and social hierarchy, and within the new era of e-government and digital public administration. Numerous reasons can be identified to explain the enthusiasm with which Open Source has been embraced by many public bodies. Perhaps the most obvious is the financial saving it affords … in governmental terms a potential vote-winner. However, this is only part of the story. There can be little doubt that government bodies and agencies are to some extent wary about the potential consequences of trusting their entire IT infrastructure to one or two private companies who may guard their software secrets closely. Open Source software is able to nullify this problem. In addition, governments are invariably charged with the responsibility of ensuring that provisions are in place to preserve a wide range of information for future generations. Open Source facilitates this in a way that proprietary infrastructures cannot.

There are numerous examples of large-scale public sector migrations to Open Source within Europe and abroad. The French Government has decided that central administration should terminate most of its agreement with proprietary vendors for the supply and use of software, meaning that national and local authorities are to use Open Source software as far as possible. The **Agency for Information and Communication Technologies in Administration** (ATICA) was set up in August 2001 to support this decision, and to coordinate the various governmental agencies and bodies towards the intended outcome. Similarly, the German central administration in June 2002 entered into a framework agreement with **IBM** and **SUSE** on the supply of Open Source products based on *Linux*, making it possible for German public administration to acquire Linux-based systems at a reduced price from **IBM**.[33] The agreement incorporates the supply of servers and workstations, as well as ongoing support from **IBM**. While this promotion of Open Source is not a law, it represents a tempting incentive to move to Open Source for decision makers within the German public sector. The United Kingdom has shown a clear commitment too, and the British ***Office* of E-envoy** issued an Open Source policy at the end of July 2002 which states that British Government and authorities will in future consider Open Source, declaring in particular a concern about being 'locked-in' to the products of single private commercial companies.[34]

The **International Institute of Infonomics** report 'Free/Libre and Open Source Software: Survey and Study' (2002) recommended and reported a widespread deployment of Open Source tools throughout European government.[35] Some prominent examples throughout Europe include:

France – The **Ministry of Culture** migrated 400 servers from Unix and *Windows NT* to *Linux* and intends to have comprehensive Linux server solutions by 2005. The **Ministry of Justice** and national crime register use a combination of Open Source tools such as the *Apache* Web server, *Perl, Samba*, and *fetchmail*, with an imminent migration envisaged from proprietary *Unix* to *Linux, PHP*, and *MySQL* and finally the **Ministry of Defence** have *FreeBSD*, an Open Source operating system comparable to *GNU/Linux*, installed within their infrastructure.[36] Illustrating the unease felt by the pro-

33 http://www.ibm.com; http://www.suse.com

34 These accounts are described in more detail in Danish Board of Technology report "Open Source Software in e-government," http://www.tekno.dk/pdf/projekter/p03_opensource_paper_english.pdf

35 Except where otherwise stated, the following accounts are from the International Institute of Infonomics report 'Free/Libre and Open Source Software: Survey and Study,' http://www.infonomics.nl/FLOSS/report/

36 http://catb.org/~esr/fetchmail/

prietary software companies to these developments, in early July 2004 **Microsoft** reduced its tariffs for Paris City Hall by more than half. The French capital had been preparing for a major computer systems upgrade and was considering the merits of a migration to Open Source.[37] The emergence of a legitimate and viable choice to proprietary infrastructure solutions can clearly only benefit end users.

Germany – In what is regarded as one of the most significant deals in the lifetime of Open Source software, the **City of Munich** officially confirmed in June 2004 that it would be transferring 14,000 municipal desktop computers from **Microsoft** *Windows* to Open Source, combining *Linux* server software, desktop software, and virtual machine technology from **VMware** to provide interoperability among heterogeneous systems.[38] In what *Bloomberg News* described as **Microsoft's** "biggest PC loss yet," the decision has led analysts to predict that *Linux*-powered PCs will grow 25%-30% in 2004, and that *Linux* will account for 6% of desktop operating system shipments by 2007.[39] In addition to this development, the **Federal Institute for Agriculture and Food** uses **SUSE** *Linux* for their intranet Web servers; the Administration of the **German Parliament** decided early in 2002 to move all servers to *Linux* and the Police of Lower Saxony expect savings of €20m over the next 10 years following a decision to move 11,000 workstations to *Linux*.

Spain – The most prominent public use of Open Source is in the Virtual Map project of the **Ministry of Public Administration**, where *Linux* is implemented on 220 servers. The **Junta de Extremadura's** *LinEx* initiative has brought Open Source software into government administration and schools, with 40,000 deployments in the region's education sector alone.[40]

© Junta de Extremadura

The LinEx desktop with applications

United Kingdom – Open Source software deployment is mainly limited to the **National Health Service** at present, where Open Source *Linux Linux*-based software was deployed to replace a proprietary *Hospital Information System Tool* after its developers became insolvent.

A number of other prominent public sector institutions have expressed interest in Open Source migration, or have already integrated Open Source software within their IT infrastructures. A recent example is Bergen, Norway's second city, which has followed in the footsteps of Munich, Germany in choosing *Linux* to underpin its technology infrastructure, moving away from proprietary *UNIX* and **Microsoft** *Windows* platforms and applications.

37 http://www.news.com.au/common/story_page/0,4057,10018498%255E15306,00.html
38 http://www.vmware.com/
39 http://www.desktoplinux.com/news/NS7137390752.html
40 http://www.juntaex.es/ See the case study below for much more on this initiative.

Humanities Institutions

Like public sector institutions, the cultural heritage sector has a vested interest in both the financial cost and the openness and accessibility of the software it uses. Many institutions have discovered that Open Source solutions offer sufficient advantages to suit all of their requirements. A prominent example is the **National Library of Australia**, which now deploys a range of Open Source applications across its server space, reflecting a willingness to invest in the skills of the library and a commitment to standardisation in general.[41] The library's Director of IT Business Systems, Mark Corbould, describes how the institution has hesitated to replace its 700 proprietary workstations with Open Source, since "*Windows* is so entrenched in the desktop space that it would take a nuclear war to remove it." This seems to justify the implementation of changes sooner rather than later, but for now the combination of *Windows* and *Linux* servers has yielded positive results.

The migration undertaken by the **San Francisco Performing Arts Library and Museum** to Open Source solutions has been similarly scaled. This was prompted by a desire to make more of limited IT spending power, and to address problems related to insufficient license ownership.[42] Wide scale replacements were made, with Open Source solutions introduced across the institution's server infrastructure, and estimated savings from a move to a **Red Hat** *Linux* system at around $2,800 (€2,265).

Given the range of Open Source advantages that are compatible and complementary with the goals and requirements of the heritage sector, it is perhaps surprising that migration to Open Source solutions has not taken place on a greater scale. A number of factors may account for this. Firstly, there is a lack of information from the Open Source movement directed towards the heritage community. With the primary motive of expanding Open Source's user base, the type of clients most frequently targeted are those in the commercial and government sectors where lucrative contracts are available and interest from other sectors can be more easily generated. It is also possible that the heritage sector still regards Open Source as a technological 'bridge too far,' and that insufficient expertise is available to fully implement these kinds of solutions.

It is possible that a number of institutions share the views expressed by the National Library of Australia, that although proprietary systems are not ideal, the resources, manpower, training services, and infrastructure required to replace them are unavailable. In fact, migration to Open Source need not be particularly onerous or costly, nor must it happen all at once. The heritage sector has a responsibility to actively seek out alternative technologies that can help facilitate its goals, and must at least consider the potential role that Open Source could play within its institutions. Most evidence suggests that this is already happening in many institutions, and that Open Source will continue to develop its foothold within the heritage sector.

Notwithstanding the above problems, examples of Open Source software use within the humanities sector are already common, and a number of these are detailed below.

41 http://www.nla.gov.au/
42 http://www.sfpalm.org/

Educational Institutions

Richard Stallman expresses a passionate belief that all educational institutions should use free software for a number of reasons. He cites the financial savings, moral influence, and additional learning opportunities that source code availability affords as major justifications.[43] Many schools and universities have responded to these and other justifications by implementing Open Source solutions within their IT environments. Projects such as *OSS-Watch*, funded by the UK's **Joint Information Systems Committee** (JISC), offer advice, support, and expertise to schools and higher and further education institutions interested in deploying Open Source solutions.[44] An *Insight* Special Report entitled 'Why Europe Needs Free and Open Source Software and Content in Schools' indicates areas in education in which Open Source can be deployed. The report concludes that OSS provides "a beneficial way to transfer knowledge and best practice."[45]

Many national educational authorities have realised that the promotion of free software for teachers enhances the adoption of ICTs in schools. The **Flemish Ministry of Education** has evaluated a collection of seventy applications from European Schoolnet's "Virtual School" repository,[46] making them available to all the schools in the Flemish part of Belgium, along with accompanying educational user scenarios. Similarly, the French **Centre national de documentation pédagogique** has led a working group that evaluated around twenty educational software packages with an emphasis on multi-platform usage and containing educational guidelines on classroom use.[47]

A recent study among IT specialists in thirty-seven tertiary education institutions in the UK and Antipodes showed that Free and Open Source software is already in place in 94% of surveyed institutions.[48] A number of commonly used Virtual Learning Environment packages (VLEs) are Open Source, including the popular *moodle*,[49] which is designed to help educators create online courses.[50]

Commercial Institutions

Without the support of the commercial world, the sustained growth in popularity currently enjoyed by Open Source would be a pipe dream. Identifying the quality of software and the significant financial saving available, the enthusiasm with which some corporations have embraced Open Source is indisputable.[51] Prevalent now in a range of often mission-critical applications, Open Source performs a range of roles, from the generic to highly specialist within both small to medium enterprises and multi-national mega-corporations. Notable examples of companies with Open Source deployments or interests include **IBM, Novell, Hewlett Packard** and **Yahoo!** These deployments range from Web servers to database infrastructures, to large-scale distributed computing projects.

43 http://www.fsf.org/philosophy/schools.html
44 http://www.jisc.ac.uk/; http://www.oss-watch.ac.uk/
45 http://www.eun.org/insight-pdf/special_reports/Why_Europe_needs_foss_Insight_2004.pdf
46 http://www.eun.org/goto.cfm?sid=220
47 http://www.cndp.fr/
48 http://www.firstmonday.org/issues/issue9_2/glance/
49 http://moodle.org
50 Open Source can also be used for content management in educational institutions. See "Zope at Duke University: Open Source Content Management in a Higher Education Context" in *DigiCULT.Info*, Issue 6, December 2003, pp. 10. http://www.digicult.info/pages/newsletter.php
51 IBM is a good example. See http://www-136.ibm.com/developerworks/opensource/ for more details.

Open Source Software Applications

Introduction

Since the early development of the *GNU/Linux* operating system, the Open Source software library has grown at an impressive rate. From an initial emphasis on server and software infrastructure code, an increasing number of Open Source projects now commit their resources and efforts to the development of desktop applications in a range of areas, including general office productivity, multimedia development, sound and video editing and manipulation and desktop publishing. As wide-ranging as Open Source software is in terms of functionality, it also varies greatly in terms of maturity, stability and performance. Given the vast array of development projects currently at different stages of development, identifying the most valuable, useful or technologically worthwhile applications can be difficult. Similarly, with such a broad range of software, locating a particular application can be intimidating, despite the range of excellent Web search tools currently available.

These problems can be addressed using a number of Open Source Web-based repositories. The two most prominent examples – *SourceForge* and *Freshmeat* – serve distinct but similar functions.[52] *SourceForge* provides free hosting and Web space for thousands of individual Open Source projects, offering centralised search tools, distribution across several worldwide mirrors and a community of users to offer advice, feedback and impressions of software projects. *Freshmeat* essentially comprises a massive index of "preferably" Open Source applications and tools for a range of platforms, together with links to each project's own pages where the software itself can normally be downloaded. Popularity details, ratings and vitality statistics are maintained and presented, offering novice users clear insights into the success and use of individual applications.

Simply browsing these impressive resources will offer valuable insights into the range of Open Source tools that exist, as well as the diversity of the subject areas and applications that are covered. In the areas of infrastructure, server applications and development software, several programs are commonly held to be as good as or even better than their proprietary alternatives. Recent times have seen a number of more generic desktop applications move towards this level of excellence, whereby an Open Source workstation is likely to offer some of the most effective software available. While continuing to refine the usability and functionality of general desktop applications, it is also a priority for the Open Source world to expand in order to satisfy the functionality requirements of more specialist users. To this end, a number of excellent applications specifically aimed at the cultural heritage sector are now available under Open Source licenses.

Generic Applications

The GNU/Linux Operating System

It was clear to Richard Stallman from the start of his campaign for Free Software that in order to have credibility a free operating system was essential. The operating system is the central program within any computer system, communicating at a low level with the

52 http://sourceforge.net; http://freshmeat.net

microprocessor and other hardware, and organising the execution and run-time of each program installed. Among the most common and familiar examples of proprietary operating systems within the personal computer market are **Microsoft**'s *Windows* and **Apple**'s *OS X*. Stallman was right: the free software movement would have had no foundations if it had had to rely upon a central proprietary program. The *GNU* (*GNU*'s not *Unix*) project was therefore begun, to develop a suite of applications that would make up a free operating system. Identifying early on that multi-platform support was a desirable characteristic, Stallman chose to base his system on the widely published core concepts that are shared by *Unix* computer systems, the only platform at the time to offer any portability. Following a great deal of success with a number of applications, eventually *GNU* lacked only a kernel to make it into a complete, fully functional operating system. The kernel represents the very heart of any operating system and manages system memory, the file system and disc operations. Fortunately a young Finnish programmer, Linus Torvalds, was concurrently building his own *Unix* compatible kernel, *Linux*, and this was swiftly integrated into the existing *GNU* code, resulting in what is now known as *GNU/Linux*.[53]

Since its initial release in the early 1990s, *GNU/Linux* has undergone almost constant refinement, and now represents a mature, stable and usable platform, incorporating most of the features of expensive proprietary *Unices*, and representing an excellent solution for both server and desktop deployment.[54] A number of successful companies distribute the system with straightforward installation packages and a variety of fully integrated applications. Some of the most popular 'distributions' include **Red Hat, SUSE, Mandrake** and ***Debian***.[55] Each can be downloaded for free from its associated Web site or purchased on disc for a small sum, fully packaged and documented. Most distributions also offer corporate packages, with full support structures more akin to commercial proprietary systems.

Emulation

Generally speaking, most IT tasks that can be undertaken using proprietary tools can also be achieved with Open Source. If an appropriate application is *not* available, the *WINE* package (Wine Is Not an Emulator) is a "*Windows* Compatibility Layer" for *Linux/Unix* which can be used to install and run many *Windows* applications.[56] Should this offer insufficient levels of performance, commercial *Linux* applications like VMware allow alternative operating systems to be installed within *Linux* virtually, running within an onscreen window.[57] This means that full software support and performance is retained, although a license is payable for *VMware*, and there is a legal obligation to own a license for a virtually installed operating system. Another proprietary alternative is to purchase **Codeweaver**'s *Crossover Office* application, which builds upon *WINE* technology and offers full *Linux* support for a range of *Windows* applications, including **Microsoft** *Office*, *Adobe Photoshop* and *Lotus Notes*, with no need to purchase a *Windows* license.[58]

53 Although the entire operating system is often referred to as "Linux," Torvalds's contribution represents only a part (albeit a very significant one) of the overall system. Open Source advocates tend to favour abbreviated terminology, probably because it is more concise and catchy, which helps in promoting the technology to corporate customers.

54 This is the standard word for a group of Unix flavours.

55 http://www.redhat.com/; http://www.SUSE.com/; http://www.mandrakesoft.com/; http://www.debian.org/

56 http://www.winehq.org/

57 http://www.vmware.com/support/linux/

58 It should go without saying that when using WINE or Crossover Office, licenses must be owned for any installed proprietary programs.

Server and Development

The success enjoyed by the Open Source software movement can be directly attributed to a number of infrastructure, server and development technologies that have been embraced wholeheartedly by the mainstream and which represent the natural choice for a number of software goals. It is in this area that Open Source has traditionally been most prominent, and this prominence seems well established. Offering performance, reliability and security equivalent to (or in excess of) proprietary alternatives, with which most of these tools are distributed at no cost, makes them extremely appealing for many enterprises, organisations and institutions.

The Apache Web Server

Alongside *GNU/Linux*, the *Apache Web* server project represents one of the most prominent success stories of the Open Source movement.[59] A Web server is an application used to make World Wide Web pages and resources available. In June 2004, *Apache* had a 67% market share of all those on the Web.[60] Straightforwardly configurable, well-documented, extremely secure and available for a wide range of platforms, *Apache* makes its closest rival, **Microsoft**'s *Internet Information Server* the Web's second choice. *Apache* can be modified to suit particular deployments, allowing system administrators to customise the services they offer, effectively creating new Web serve rs based on the *Apache* model.

Database Servers

It is common for any institution, regardless of size, to have digital information that would benefit from the efficient, structured storage opportunities offered by a database. Three prominent Open Source alternatives exist, each with their own individual strengths and each offering a maturity and depth of functionality making them among the most effective of all database servers. *MySQL* is perhaps the best known, and compares extremely favourably with most proprietary equivalents, particularly in terms of speed and stability.[61] It is particularly valuable when used for underlying Web databases due to the way that it deals quickly with multiple connections. *PostgreSQL* and *Firebird* are other notable examples, and tend to be regarded as more functionally complete than *MySQL*.[62] While neither matches the heavyweight functionality offered by the leading proprietary database (**Oracle**), unless an application has special requirements P*ostgreSQL* and *Firebird* are both likely to incorporate all of the necessary features.[63] While *MySQL* and *Firebird* both run natively on a range of platforms including *Linux* and *Windows, PostgreSQL* is less flexible, with no native *Windows* ve rsion available. *MySQL*'s significantly larger user base accounts for its more comprehensive documentation and help structures, as well as its increased stability.[64] Prominent *MySQL* users include **Google, Cisco, Sabre Holdings, Hewlett Packard, NASA** and **Yahoo!**

59 http://www.apache.org
60 http://news.netcraft.com/archives/web_server_survey.html
61 http://www.mysql.com
62 http://www.postgresql.org/; http://firebird.sourceforge.net/
63 http://www.oracle.com
64 A fuller comparison of the relative merits of each can be found at http://www–css.fnal.gov/dsg/external/freeware/pgsql-vs-mysql.html and http://www.databasejournal.com/features/postgresql/article.php/3288951

Programming Languages

A number of programming languages have been released under Open Source licenses, and have attained ubiquitous status in a range of computing areas. Three of the most prominent are the scripting languages *PHP* (*PHP* Hypertext Preprocessor), *Perl* (Practical Extraction and Report Language), and *Python*.[65] The latest version of *PHP* offers extensive Object Oriented support, used in the creation of dynamic Web pages. Popular among Web developers due to its fast parsing and flexibility, *PHP* is also extremely versatile and comes with many inbuilt interfaces. Database connectivity is straightforward; while *PHP* is most commonly associated with *MySQL* it can connect to any ODBC-enabled database. *Perl* offers similar functionality to *PHP*, but with more general deployments than the Web. True, *Perl* is frequently used to add dynamic functionality to Web pages, but it also handles more mundane tasks like system administration and data processing. *Perl*'s rich support for regular expressions also makes it useful as a text manipulation language, its flexibility suggests that it can play a role in most computing tasks. Like both *Perl* and *PHP*, *Python* is frequently used in a Web environment. Combining powerful capabilities with a simple syntax, *Python* also has interfaces to numerous system calls and libraries. Additional modules can be developed using C or C++, extending the functionality to suit individual requirements. All three programming languages are portable, supporting a range of platforms including *Linux*, *Windows*, *Mac*, and *OS/2*. Because the languages themselves are open, even if they should fall into decline or obsolescence, existing code will be able to be re-purposed for a future system configuration and executed with no risk of loss.[66]

Several prominent Open Source applications are written in the *PHP*, *Perl* and *Python* languages. These often utilise a combination of *GNU/Linux*, the **Apache** Web server, a ***MySQL*** database, and one of the '**P**' programming languages, with the resulting combination often abbreviated as **LAMP**. Examples include the application server tool *Zope*, and the content management system *plone* that is built upon it.[67]

Miscellaneous

To further describe the various Open Source software packages that have established major footholds within the Internet infrastructure would take a great deal of space; suffice to say that OSS applications exist for almost every subject area, from eGovernment to academia and games.[68] If looking for something particular, the best idea would be to consult *SourceForge* or *Freshmeat*, or keep an eye on the Open Source Development Network's free daily email updates. Further examples of popular and very successful tools include *Sendmail*, the world's most used email server software, *Bind*, the most commonly used domain name system server, and *Apache Jakarta Tomcat*, one of the most popular servlet

65 http://www.php.net; http://www.perl.com; http://www.python.org/

66 Sun Microsystems are currently involved in a public debate over the merits of opening up their currently closed-source Java programming language. Developments here will be well worth watching, given Java's prominence as a platform-independent, Web-friendly language.

67 http://www.zope.org/; http://www.plone.org/

68 Of particular interest to cultural heritage institutions are several small applications and tools discussed in the *DigiCULT.Info* newsletter, including *Greenstone* (Open Source software for digital libraries) http://www.greenstone.org. See also "Open Source Tools" in *DigiCULT.Info*, Issue 7, April 2004, pp. 31, "PLEADE – EAD for the Web" and "NZ Electronic Text Centre" both in *DigiCULT.Info*, Issue 6, December 2003, http://www.digicult.info/pages/newsletter.php

containers in use on the Web, providing an infrastructure for the delivery of Web based Java programs.[69]

Desktop and Productivity

Its traditional arena of dominance since the early 1990s has been in servers and network infrastructure, but the recent upsurge in popularity of Open Source has led to the development of a number of mature and functionally rich desktop applications that measure up well against their expensive proprietary peers. Although a notable gulf continues to exist in some areas, Open Source desktop applications have been responsible for the development of a range of extremely innovative features that have subsequently found their way into commensurate commercial applications, giving the lie to the accusation that Open Source stifles innovation.

The Mozilla Project

Made up of a number of individual programs, the **Mozilla** project represents one of the most successful Open Source desktop application projects, offering a level of maturity, functionality and innovation that matches and surpasses much proprietary software.[70] At its forefront is the **Mozilla** package, which offers Web browsing, email, newsgroup and IRC access, together with a Web development package in a single, customisable interface. Offering full compliance with all Web standards the project –which is based on the formerly closed-source *Netscape* application – offers an excellent level of functionality, ease of use, and security against malicious Web objects. It is particularly in the area of security that **Mozilla** outshines **Microsoft**'s frequently vulnerable *Internet Explorer*, but it also offers improved functionality, with a built in pop-up blocker and integrated search facility that *Internet Explorer* does not offer as standard.

The **Mozilla** project has also developed a range of sister products. *Mozilla Firefox* is a stripped down, lightweight Web browser with support for the addition of separate modules of functionality, or *extensions*.[71] It aims to be fully customisable, with optional features that introduce exciting navigational and development possibilities. *Thunderbird* is another project, essentially promising the same things for email as *Firefox* promises the Web.[72] Lightweight and secure, it supports all major protocols and can be fully customised to suit environment or user preferences. All **Mozilla** tools are available for *Windows, Linux*, and *Mac OS X*.

The **Mozilla** project has inspired and enabled the development of a number of other applications, including the defect-tracking system *Bugzilla*, which facilitates the reporting of errors from a wide number of applications, ensuring their continued development and refinement.[73]

69 http://www.sendmail.org/; http://www.isc.org/index.pl?/sw/bind/; http://jakarta.apache.org/tomcat/
70 http://www.mozilla.org/
71 http://www.mozilla.org/products/firefox/
72 http://www.mozilla.org/projects/thunderbird/
73 http://bugzilla.mozilla.org/

Evolution Groupware

In addition to mail access, many institutions and users rely upon the availability of comprehensive organisational packages that facilitate the management of time, resources, and other communications. The standard proprietary package offering this functionality is **Microsoft**'s *Outlook*, and this has remained a successful and popular tool since its introduction.[74] **Novell**'s *Evolution* seeks to offer similar functionality, but under a GNU GPL Open Source license.[75] It has unequivocally succeeded, and offers a range of features, including mail, calendar, to-do lists, address book, scheduling, personal digital assistant (PDA) synching, and connectivity with **Microsoft** *Exchange Server* or **Novell**'s *GroupWise* for information sharing.[76] With its attractive and intuitive interface, *Evolution* is a key reason why an Open Source based desktop infrastructure is now viable within any size of institution, organisation or company.

OpenOffice.org

With *Evolution* representing the communications hub for the Open Source desktop platform, it is vital that a robust, functionally rich productivity suite is available for the general administration that forms a major part of the activity of most institutions. With the numerous problems associated with the proprietary and hidden nature of **Microsoft**'s *Office* formats, institutions should be wary of regarding *Office*-encoded data as archivable. *OpenOffice* is a massive project, backed by **Sun Microsystems** to develop a comprehensive and transparent suite of tools, including word processor, spreadsheet and slideshow presentation software, that writes to Open Standard formats defined in XML.[77] Currently on version 1.1, the project has enjoyed great success; in file size terms it is the largest Open Source application. 'Read' and 'write' support for **Microsoft** *Office* formats is included, but since these are not publicly documented, errors are occasionally encountered, particularly when dealing with complex structures such as tables. Objects such as images, plugins, videos and charts can be embedded as straightforwardly as with **Microsoft** tools. There is no support for *Visual Basic for Applications* (VBA) macros, since this is a proprietary **Microsoft** technology, but scripting is possible using the integrated *StarBasic* syntax.

An **eWeek** survey between *OpenOffice* and **Microsoft**'s *Office 2003* illustrates the relative merits of the two suites.[78] The general consensus is that while *OpenOffice* represents a wonderful free package, with several unique features such as built in pdf-writing support and the integrated nature of the individual applications, it lacks the polish and some of the more advanced functionality of the latest version of *Office*. *OpenOffice* 1.1 is regarded as approximately functionally equivalent to **Microsoft**'s *Office 97*, albeit with many additional features and a greater level of reliability. Of course, this need not represent a problem, since the majority of ordinary users is unlikely to have requirements that cannot be met by the earlier version. However, when Jack Wallen Jr. of **ZDNet Australia** writes "if you can do it in **Microsoft** *Office*, you can do it in *OpenOffice*.org… for free," it should be

74 http://www.microsoft.com/outlook
75 http://www.novell.com/products/evolution/
76 http://www.microsoft.com/exchange/; http://www.novell.com/products/groupwise/
77 http://www.openoffice.org
78 http://www.eweek.com/article2/0,1759,1570801,00.asp

borne in mind that *OpenOffice* still has some way to go before matching all of the functions of *Microsoft*'s flagship application.[79]

GNU Image Manipulation Program (GIMP)

A further example of a mature and very useful Open Source program is the *GNU Image Manipulation Program (GIMP)*.[80] This is a feature-rich image editor, supporting a range of formats and plugins, and representing a viable alternative to expensive packages such as **Adobe**'s *Photoshop* and **Jasc**'s *Paint Shop Pro*.[81] Similar to *OpenOffice* in that its feature-set is equivalent to slightly older versions of proprietary tools, it is likely that for all but the most demanding of users *GIMP* will be powerful enough to meet requirements.

Open Source and the Cultural Heritage Sector

Introduction

A range of tools designed for the achievement of specific, specialist goals is now available under Open Source licenses. A number of factors make the Open Source model particularly suitable for the Cultural and Heritage world, and this has led to concentrated development in this area. The traditional financial limitations, requirements for Openness and 'future-proofing' within software and the often physically distributed nature of organisations and projects are all problems that Open Source can seek to mitigate.

The cultural heritage sector will have much to thank Open Source for, charged as it is with the responsibility of preserving materials for future generations. The decade between the beginning of the Internet boom and the present day has seen a great deal of material created by cultural institutions; we can only be confident that a small proportion of this will survive. For the maintenance and preservation of born-digital material, the continuing development and proliferation of Open Source and Open Standards represents hope for the future. It is essential that these philosophies gain popular support before much more content is created; it is more than likely that this will save massive amounts of time, effort and money in future retro-conversion.

The following sections detail a number of prominent Open Source applications aimed specifically to meet cultural heritage requirements.

Koha Open Source Library Software

Koha is a maturing Open Source integrated library system (ILS) that can be used to handle cataloguing, circulation, acquisition of new media, and patron access.[82] Functionally comparable with proprietary tools such as *Innopac* by **Innovative Interfaces**, *Advance* from **Geac**, and *Voyager* by **Endeavor Information Systems**, *Koha*[83] is distinguished by

79 http://www.zdnet.com.au/insight/0,39023731,20270300,00.htm
80 http://www.gimp.org/
81 http://www.adobe.com/products/photoshop/main.html; http://www.jasc.com/products/paintshoppro/
82 http://www.koha.org/
83 Koha: A New Zealand Maori word for "gift" and/or "parting instruction". Zoran Ognjanovic also reports in *DigiCULT.Info Issue* 7 (2004), pp.41, that the National Digital Library of Serbia is close to implementing *Greenstone*. Available online at http://www.digicult.info/downloads/dc_info_issue7_lowres.pdf

its free status, distributed under the GNU GPL license.[84] With support for most international standards such as *MARC* and *Z39.50, Koha* is a valuable resource for libraries. Institutions can save the money that would normally be committed to acquiring the ILS software, and use this to contract programmers to customise the application for their own specific requirements. **Philanthropy Australia** installed the software in mid 2002, and resource centre librarian Louise Arkles has described how the "issues" with proprietary tools were not a problem with *Koha*, as money saved with it "would enable us to put money into customising it."[85] To illustrate its scalability, *Koha*'s online FAQ reports that the biggest library using the software so far is **Nelsonville Public Library**, Ohio, USA, with 250,000 items, and an annual circulation of 600,000.[86]

Greenstone Digital Library Software

Greenstone is a suite of tools for building and distributing digital library collections. It grew out of the *New Zealand Digital Library Project* at the **University of Waikato**[87] and is developed and distributed in cooperation with the **United Nations Education, Scientific and Cultural Organisation** (UNES**CO**) and the *Human Info* NGO.[88] Compatible with *Windows, Linux, Mac OS X*, and any other *Unix*-based system, Greenstone has already established itself quite prominently and has been used to distribute digital library materials by a number of institutions. *Greenstone* is capable of presenting very large numbers of multi-format documents within a common, intuitive interface, and published content is searchable, browsable and fully maintainable using metadata information. Projects that have benefited from the use of the *Greenstone* software as their digital library's backbone, illustrating its built-in multilingual support, include the **Stuttgart University of Applied Sciences** *Hochschule der Medien* project, the **Welsh Books Council**'s *Books from the Past* project, the Milanese **Vimercate Public Library**'s *Mirabilia Vicomercati* project aimed at the digitisation of local history primary sources, and *Project Gutenberg*, an ongoing project to produce and distribute free electronic editions of a variety of literature.[89]

The *Greenstone* project publishes a great deal of documentation on the use and development of the system, as well as the process of taking a collection from paper to a digital collection format. Formal training sessions are also offered in the use of the software, and *Greenstone* welcomes and encourages contributions and enhancements from users.[90]

EROS Image Content Retrieval System

Billed as an "Open Source multilingual research system for image content retrieval dedicated to conservation-restoration exchange between cultural institutions,"[91] *EROS* repre-

84 http://www.iii.com/; http://www.library.geac.com/page/upadvance_LIB.html; http://www.endinfosys.com/prods/voyager.htm

85 http://www.philanthropy.org.au/; http://www.computerworld.com.au/index.php/id;534895878;relcomp;1

86 http://koha.org/faq/; http://www.athenscounty.lib.oh.us/

87 http://www.greenstone.org; http://www.sadl.uleth.ca/nz/cgi-bin/library

88 http://www.unesco.org; http://humaninfo.org/

89 http://digbib.iuk.hdm-stuttgart.de/gsdl/cgi-bin/library; http://www.booksfromthepast.org (also available in Welsh, as *Llyfrau o'r Gorffennol*); http://www.mirabiliavicomercati.org/; http://www.gutenberg.net/

90 For a fuller account of Greenstone functionality, see the dlib article at http://www.dlib.org/dlib/october01/witten/10witten.html. Extensive details of Koha, Greenstone and a number of other Open Source applications relevant to libraries are available from the Open Source Systems for Libraries Web site, http://www.oss4lib.org.

91 http://www.c2rmf.fr/documents/c2r_eros.pdf

sents a collaborative project between the **Centre de Recherche et de Restauration des Musées de France and Celartem Technology**.[92] In fact, *EROS* is a high performance and flexible database system configured to handle information on works of art, including detailed information on the works themselves as well as information about any digital images of the works that exist, restoration reports and image recognition meta-data. The system also incorporates advanced multilingual searching and indexing capabilities as well as a high-resolution image viewer and image content recognition modules.[93] With the means to present data in XML or other formats, it is also possible to link databases to share information with other institutions.[94]

Museum Collection Management for Microsoft Access

A *Windows*-only Open Source application, *mcm-f-access* originated out of a desire to replace an unstructured, flat-file collection database in use at the **Charles A. Wustum Museum**.[95] It implements a straightforward structure for museum collections within a **Microsoft** *Access* database, and incorporates a range of functionality, including a switchboard front-end with limits on user menus, password protection, the ability to automate label printing for exhibitions, exhibition reports, the ability to sell and/or rent artwork, together with agreement forms, exhibit labels and sales reporting, reporting of artwork displayed in shows, catalogue output of exhibits, and the opportunity to identify artwork using digital images. The fact that the application interfaces with a popular proprietary software package emphasises the fact that using Open Source is by no means an 'all-or-nothing' matter.[96]

Case Studies


© Junta de Extremadura

The LinEx desktop

LinEx[97]

Bordering Portugal to the west, the Extremadura region comprises Spain's two largest provinces, Badajoz and Cáceres. Extremadura has an area of 41,602 km² and a population of approximately one million inhabitants, giving a population density of less than twenty-six inhabitants per square kilometre. Fifty seven percent of the

92 http://www.c2rmf.fr; http://www.celartem.com
93 Open Source applications are also being used to handle moving image collections. See, for example, "The Open Video Project: Building an open source video archive" in *DigiCULT.Info*, Issue 5, October 2003, pp. 22 http://www.digicult.info/pages/newsletter.php
94 For more details see http://eprints.ecs.soton.ac.uk/archive/00007743/01/c2r_eros.pdf
95 http://mcm-f-access.sourceforge.net/; http://www.ramart.org/08_wustum_museum/index.php
96 See also "New Open Source Software for Content and Repository Management" in *DigiCULT.Info*, Issue 6, December 2003, pp. 16 http://www.digicult.info/pages/newsletter.php
97 This case study is based on an email interview with LinEx developer Dario Rapisardi in August/September 2004. http://www.linex.org/

region's population lives in municipalities with fewer than 10,000 inhabitants. The regional government, the ***Junta de Extremadura***, is keen to develop projects and actions towards a networked society, including the establishment of the ***Fundación para el Desarrollo de la Ciencia y la Tecnología en Extremadura*** (Foundation for the Development of Science and Technology in Extremadura) in 1995, which examines the potential for synergy between companies, technological centres, and regional government.

In 1997, a plan for the development of the Information Society in Extremadura was drawn up. The aim of this plan was to promote and assist in the uptake of information and communication technologies in the region, based on the development of the Intranet *Extremeña*. Through this intranet, the regional government intends to provide broadband Internet access to every administrative building, educational institution, health centre, hospital, and public library, connecting 1400 points across 383 municipalities, including remote and sparsely populated locations where access to telecommunications is not always easy.

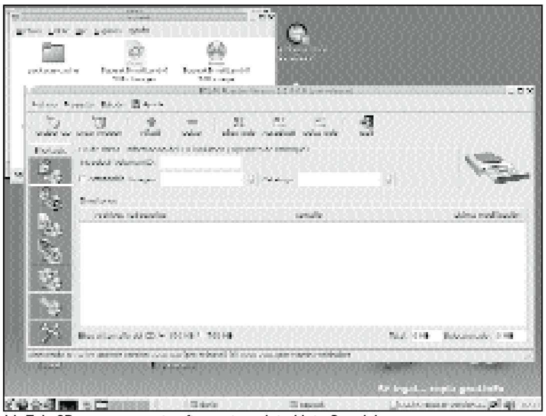
One of the Junta's key policies is the development of the ***Red Tecnológica Educativa*** (Educational Technological Network), which aims to have one computer for every two students in each school in the region. To meet this need, the **Junta de Extremadura** turned to Open Source software, specifically the *Linux* operating system. In addition to the economic benefits of Open and Free Software, the major gain lies in its adaptability: its open nature allows the system to be continually adapted for the needs of educational systems and the public administration alike. After months of tests, studies and formation with *Linux*, the Junta decided to build its own ***GNU/Linux*** distribution, *LinEx*. The LinEx project began in 2002, as the latest move in the Junta de Extremadura's economic and social plan to provide "connectivity and Technological Literacy to every citizen, regardless [of] the place they live in."[98] The first version of *gnuLinEx* was developed in 2001 by private company **Andago**, although it was never installed in schools.[99] The first version of *LinEx* to be installed in schools was *LinEx 3.0rc2* in the summer of 2002, and since then all *LinEx* development has been carried out exclusively in-house.

A couple of factors prompted the decision to make *LinEx* Open Source. Initially, the main issue with proprietary software was its cost. To develop the operating system in house would be extremely expensive. Buying all the software needed by education was impossible too (not just the operating system). In cases like this, using open source software looks like the only possible choice. After that, using *LinEx* showed it was the best option, since the customisation made possible things that could never be done with proprietary software. The development of an operating system from the ground up would require more expertise than the Junta could manage in-house. For that reason, the *Linux* operating system was used as the base for *LinEx*. Specifically, *LinEx* is based on the ***GNU/Linux*** distribution *Debian*, and much of its software was reused.[100] The work involved in *LinEx* was basically the adaptation of *Debian* software to meet local needs. The new elements were mainly translations and minor software modifications, and mostly in terms of educational programs. Some other applications were translated and included, such as *Nvu* (a *Dreamweaver*-like tool), the *GNOME* printing tool, *foomatic*, and configuration tools not included in *Debian*.[101] *LinEx*'s star application is *Squeak*, a powerful multimedia

98 http://www.linex.org/linex2/linex/ingles/antecedentes_ing.html
99 http://www.andago.com
100 http://www.debian.org/
101 http://www.nvu.com/; http://www.gnome.org/about/; http://sourceforge.net/projects/foomatic/

and educational environment.[102] The Junta de Extremadura also has in-house developers developing e-toys, translating the tool interfaces, generating documentation, and keeping users up to date on the system. The educational tools change continually. The geography program *KGeography* was modified to include Spanish regions and provinces, and another tool was modified to accept Spanish verbs rather than English.[103]

In general, the original authors of the software have been happy to collaborate on the project, integrating new modifications into their original software. Since *LinEx* is based on *Debian*, it is a direct result of the efforts of that community that seems pleased with the project itself and is always happy to share experiences and opinions. Communities of users have emerged, contributing additional applications and suggestions. Given *LinEx*'s youth (it is less than three years old), these results are impressive.



© Junta de Extremadura

LinEx's CD management software translated into Spanish

The *LinEx* Web portal is a key part of the integration of *GNU/LinEx* into Extremaduran society. As a main objective, it defines what *GNU/LinEx* contains, and allows users to learn about its development. Given the number of distribution packs in circulation, without a Web portal it would be incredibly difficult and time-consuming to provide technical support for all of them. All users have access to an FAQ list and user-friendly technical support: the Web portal looks exactly like the distribution. The Web portal also provides news and information on Free and Open Source software and the Information Society in general, and fulfils a social function as a meeting point for the *LinEx* community.

Personnel roles involved in the development of the project included developers, user support, and promotions staff. Some external expertise was required, with two developers from Argentina now living and working in the region. Additionally, in common with all major Open Source applications, many people from all over the world help with the project, and anyone who wants to play a part is welcomed.

LinEx has been a success. The nature of Free Software has allowed the customisation of the systems used in 68,000 school computers. This would not have been feasible with closed proprietary systems. Evaluation of the project has also been positive, and users provide the developers with feedback about the behaviour of the operating system, as well as bug reports. In financial terms, running *LinEx* costs around €200,000 each year. The cost of buying *Windows* licenses, not including any other software, would be €20,000,000.

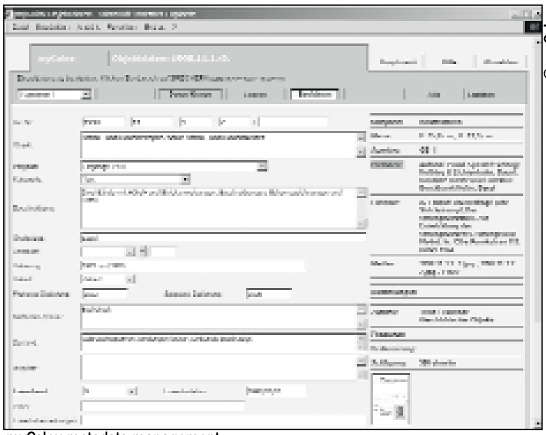
LinEx has won a number of awards, the most recent of which were several prizes from its beginnings, including a Regional Innovation Award by the European Union, given to the President of Extremadura in April 2004. In the summer of 2004, an agreement was reached which will see the **Junta de Extremadura** working in conjunction with the **Junta de Andalucia** in the development of *LinEx* and *Guadalinex*. Under current plans, the administrations (which share common needs) will work together on two regional

102 http://www.squeakland.org/
103 http://kgeography.berlios.de/

Linux distributions with a considerable common base. Many other autonomous communities and governments from all over the world have come to Extremadura seeking advice regarding similar matters.

In August 2004, Spanish President José Luis Zapatero announced the establishment of a new national centre for research and development of Free Software, the ***Centro Estatal de referencia para el desarrollo y la investigación avanzada de Software Libre***, to be sited in Extremadura. This will also act as a reference centre, and marks a significant step towards the more widespread adoption of Open Source software throughout Spain and beyond.

myColex[104]



© myColex

myColex metadata management

Museum collections are an integral part of the cultural heritage of a society. The documentation that surrounds these collections is an important part of this heritage, and curators have a duty to maintain it carefully, preserving it for future generations. Another of the staple duties of a museum is to encourage the documentation of collections in a simple and inexpensive manner, thus enriching the heritage and preventing the illegal trafficking of cultural goods. The **Historisches Museum** in Basel, Switzerland[105] is home to one of the earliest public museum collections (the famous *Amerbach Kabinett*), with collection documentation dating back to the 16th century. In 2001, the museum began looking for a way to preserve its ongoing documentation work digitally for the long-term. The resulting project was *myColex*, an Open Source system developed with the aim of providing a flexible, portable, straightforward and adaptable collection documentation system for museums, private collectors and galleries.

In terms of collaborative development and reduced costs, Open Source Software clearly and demonstrably meets cultural institutional needs. As Stefan Bürer, Head of Documentation Services and IT at the Historisches Museum and chief developer of *myColex* says: "There is an inherent affinity between culture and Open Source. A work of culture is open for interpretation by everybody; it is an open source for further developments and other works of culture. To spread the use of Open Source, I think it's important to raise the awareness of independence. There is nothing bad about proprietary software, but it's bad when public project announcements, for instance, have restrictions for the use of proprietary software. Opening these projects to Open Source Software would boost business opportunities for software enterprises, and would hopefully lower the costs of software projects."

From idea to realisation, the *myColex* project took around eighteen months, including migration from a **Microsoft**-based platform to an entirely OSS landscape. Personnel roles were fairly standard: the initial application was built by the application developer, then

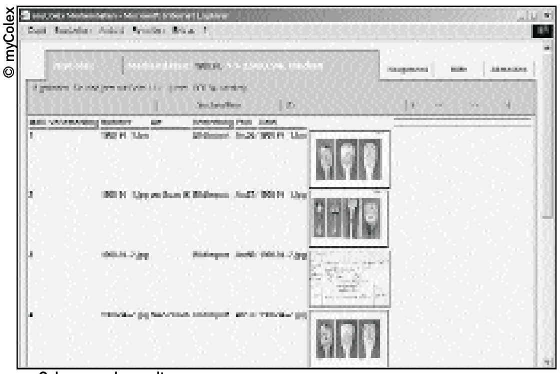
104 This case study is based on an email interview with Stefan Bürer, Head of Documentation Services and IT at the **Historisches Museum Basel**, Switzerland, in May/June 2004. http://mycolex.collector.ch; http://sourceforge.net/projects/mycolex

105 http://www.historischesmuseumbasel.ch/

users suggested enhancements and the developer tried to implement these in future versions. After the proof of concept was made and basic problems solved, user groups were consulted and hints accepted from colleagues and friends to help solve technical problems. In terms of the Open Source community, the forerunners of *myColex* (and, indeed, m*yColex* itself) are in use in a number of Swiss museums, and there has been much input from these institutions on a functional level. While the implementation and realisation of *myColex* has been done by Bürer alone, as the number of installations of the software has risen the community has grown, and contributions have come in, mainly related to translations and documentation. As Bürer points out, collaboration today means translations into other languages. The next version of the software, which was due to be released in the second half of 2004, would be published as a concurrent versions system (CVS) in order to allow others to contribute to the project on a functional level; contributions from others serve to strengthen and refine the software. In order for this to happen the system design must be clear and object-oriented, and it is hoped that *myColex* has achieved this. Other problems came out of configuration issues. For Bürer it was "amazing how efficiently problems could be located and solved with the many sites and user groups on the Internet."

The decision to make *myColex* Open Source stemmed from keeping an eye on the future. The availability of the source code and the independence of platforms, which is crucial to many Open Source software projects, make this kind of software suitable for electronic long-term archives: a system completely realised with Open Source Software should be re-buildable with an appropriate compiler today or in the future on almost any platform.[106] Furthermore, there is little or no dependency on software corporations and proprietary components. By virtue of its Open Source nature, the *myColex* source code can be adapted to meet special needs, which is crucial for museums, which will inevitably have a diverse range of emphases. (For example, the **Historisches Museum** collections cover many different subject areas, including archaeology, ceramics, clocks, coaches, coins, textiles, furniture, silverware, weapons, household utensils, musical instruments, sculpture, paintings and so on, with about half a million items).

© myColex



myColex search results

Open Source suits organisational needs well, since the development methodology preserves and extends understanding of particular software tools, and reduces the risk of problems in the event of an important team member leaving the organisation. From a long-term museum documentation archiving perspective, it is best to realise *myColex* completely with Open Source software components, but it will work with proprietary software as well. Of course Bürer looked for the best fitted tools, and there is a wide choice of OSS-components. The favoured *OS* is *Linux* (but could be *Windows* or *OS X*), the Web Server is *Apache* (although the system should work

106 Platform independence is not specific to Open Source software, nor is Open Source software necessarily platform independent. Of course, it could be argued that if you have the source for one platform you can rewrite it to run on another because you understand how it works, but this may be onerous under many circumstances.

with a tuned ISS as well), the DBMS is *MySQL* (the next version will see a database abstraction layer, which could work with *PostgreSQL, Oracle, MS-SQL* and the like), and *PHP* was used for the scripts: this is the only layer which could not be replaced easily.

The *myColex* software has many ancestors, and it evolved in the usual way of a database-application. It began with a desktop database (*MS-Access*), which gradually grew to a Client-Server application developed with **Microsoft** *Visual Studio*. Each step meant a redesign of the application. On a programming level there was almost no reuse of existing code, but many concepts were further refined. This involved a significant amount of work, but also provided a chance to clean up the application architecture as a whole. Much work was needed to integrate the (somewhat outdated) *Office 97* for printing output, which was managed with a template system. The moral of the story is that if openness is desirable it may be worth looking at all of the components, deciding what could be done better with OSS than with proprietary software, and replacing these components individually.


© myColex

myColex calendar

There are many OSS resources which were reused for *myColex*'s development: *FastTemplate* as a template system, Isaac McGowan's *phpEventCalendar*, Geir Landrö's *dTree* for the tree-view, and Mihai Bazon's *DHTML Calendar*.[107] Many hints and references in the user groups and websites were of great help and the documentation used (for instance Stefan Münz's *SelfHTML*, and the Help Files of the *PHP* Documentation Group)[108] was usually of outstanding quality. During the system development a steady flow of information and assistance came through **CIDOC**, the **International Council of Museums** (ICOM), the documentation group **VMS-AMS**, and other working groups.

The decision to make *myColex* Open Source was based on Bürer's previous experiences with proprietary development models, and was made for conceptual reasons rather than on technical or financial reasons: with regard to long-term archiving issues, openness was seen as a key attribute. However, other benefits have arisen from the technical and financial side as well. The stability and open development of OSS concepts, the use of open standards and protocols, and the independence from vendors are cited as three major reasons why archive applications may benefit from the move to Open Source.

When asked about the preconceptions that sometimes accompany Open Source, Bürer is forthright: "People with an IT background usually feel sympathy for OSS; most other people don't care." The best arguments for going with an Open Source solution are the long-term archiving question and the issue of independence from specific, proprietary systems. (For cultural institutions financial considerations may be high on the agenda as well.) But OSS is far from being a brand label (and it is arguable whether it should be), and the business opportunities are as well developed as with commercial licensed software.

The next major version of *myColex* is due to be released in late 2004, and will see a

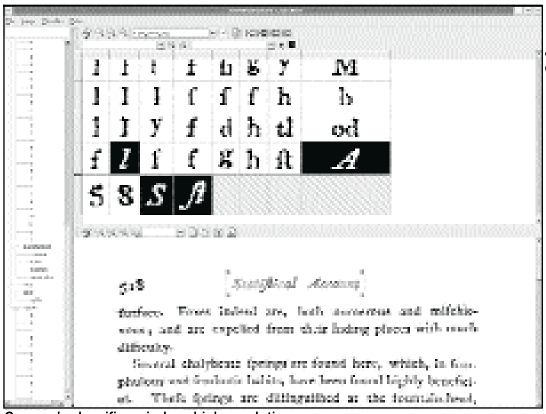
107 http://sourceforge.net/projects/fasttemplate/; http://www.destroydrop.com/javascripts/tree/; http://dynarch.com/mishoo/calendar.epl

108 http://de.selfhtml.org/; http://www.php.net/docs.php

database abstraction layer, as well as some improvements in the user interface. For example, for the OSS scene, *myColex* might be just another database, but its real importance is for cultural heritage institutions, not only because of the long-term preservation of digital data, but also because it opens the field of digital documentation for institutions with little financial clout.

myColex has been presented on several occasions at national and international conferences.[109] The concept was published in several articles in the **VMS-AMS** bulletin, as well as in the **CIDOC** proceedings. It has been included in surveys,[110] and is now available on *SourceForge*.[111] On the functional and bug level, feedback has been submitted from users quite regularly. In terms of uptake, *myColex* has had a number of downloads and requests for implementation, from Switzerland, Germany, and particularly the new EU member states. In the **Historisches Museum** itself, *myColex* is used by a network of around fifty users, covering all aspects of collection management from acquisition to curation, conservation, storage, object loans and media-, exhibition-, event-management. Bürer himself accompanies most of the Swiss implementations, and so far these have seemed to satisfy the needs of the users. Aside from the long-term archiving issue, OSS is also a suitable marketing channel for small-to-medium-sized IT enterprises, which tend to earn a living from the services they offer rather than through the production of shrink-wrapped software.

Gamera[112]



© Gamera

Gamera's classifier window: high resolution

Vendors of commercial OCR packages tend to maximise their market share by optimising their programs to work best on commonly occurring types of documents: generally printed business correspondence. It is unlikely that the demand for recognisers of antiquarian cultural heritage materials will ever be sufficient to support the development of commercial shrink-wrapped systems. Therefore collection managers who wish to automate the extraction of symbolic data from digital images must use their limited resources to build highly specialised systems. *Gamera*'s aim is to assist in this process by reducing the time needed for development of such systems. Another important aspect of Gamera's flexibility is that it allows for the creation of applications that aren't necessarily focused on "transcription." For instance, with the medieval manuscript collection, scribe identification and illumination finding are tasks that important to medievalists.

Gamera is a programming toolkit for building document recognition applications. It allows document image analysis (DIA) researchers and document experts to build software

109 The VMS conference in Bern, Switzerland, 01/02/2003, and the CIDOC/ADIT 2003 conference, Saint Petersburg, Russia, 04/09/2003. http://cidoc2003.adit.ru/english/program.asp
110 See for example http://www.kulturinformatik.com/softwarevergleich/
111 http://mycolex.sourceforge.net
112 This case study is based on an email interview with Michael Droettboom of the Digital Knowledge Center, **Johns Hopkins University**, in May/June 2004. URL: http://gamera.sf.net/

programs that extract symbolic representations from digital images.[113] Gamera was initially developed at the **Digital Knowledge Center** (DKC) of the **Johns Hopkins University's Sheridan Libraries**.[114] Development began in mid-2000 with a team comprising two full-time developers and two managerial contributors. While the system was intended to be Open Source from the very beginning, its developers felt that the initial development team should stay small and localised until the core functionality was mature. The work is funded through grants from the US **National Science Foundation and the Institute of Museum and Library Services**.[115] Private donations came from the family of Lester S. Levy, who also donated a sheet music collection that has become the subject of a *Gamera* application.[116] *Gamera* has been used locally to build DIA applications, to varying degrees of completion, for common (Western) music notation, medieval text manuscript and eighteenth century census data. Outside of the *Gamera* group, it has been used for Renaissance lute tablature and Navajo language documents.[117]

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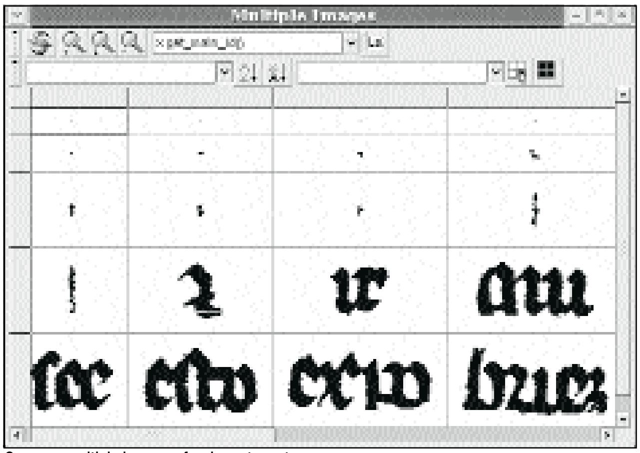
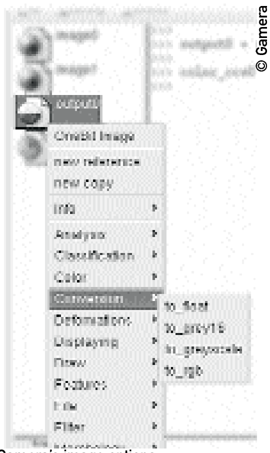


Gamera multiple images of a character set

© Gamera



Gamera's image options

The *Gamera* toolkit has two main parts, each of which aims to reduce development time: (i) a set of reusable software components for building these applications; and (ii) a graphical user interface (GUI) for experimentation and training. To this core foundation, developers can add tools and processes specific to their document domain. *Gamera* is built using *C++* for the pixel-level image processing, and *Python* for higher-level analysis, automation and the GUI. Being Open Source it is available at no cost, and customisable beyond what would be possible under a closed-source model.[118]

As the number of users of a system grows, it becomes increasingly difficult to make major changes. For this reason, *Gamera* remained in incubation until January 2004 when it was released on ***SourceForge***.[119] An important factor in the decision to make *Gamera* Open

113 Symbolic representations add a great deal of value to digital document collections, as they are more readily searchable and can be used for statistical analysis. For more on this see "Making Handwritten Archives Documents accessible to the Public with a Document Image Analysis System" in *DigiCULT.Info*, Issue 8, August 2004, pp. 21. http://www.digicult.info/pages/newsletter.php

114 http://dkc.mse.jhu.edu/

115 http://www.nsf.gov/; http://www.imls.gov/

116 http://levysheetmusic.mse.jhu.edu/

117 It should be stressed that while Gamera is a tool used to build such systems, it does not perform these specific tasks without extension and customisation.

118 This level of customisability is important in order to meet the diverse needs of unusual document types. It is unlikely that such a system would be successful in terms of financial gain or usage in a closed-source model.

119 http://sourceforge.net/

Source was the team's limited resources. It is currently managed by a single developer whose primary job function is to work on *Gamera*. There is also a part-time student-employee developer. A second full-time developer joined the team in June 2004. Through *SourceForge*'s collaboration features, *Gamera* has a distributed team of users that helps to find and correct bugs and add features. While the coordination of this work requires some effort, it is considerably less time consuming than doing all of the development work in-house.

© Gamera

Gamera's autocompletion function

As each new major feature is added to *Gamera*, a literature search is performed to avoid duplication of effort and to reuse existing Open Source code whenever reasonable. More than ever before, there is a wealth of riches of Open Source code available. However, there may be technical (rather than legal) restrictions on the use of code. Problems may occur when developers want to use code written in another language, code that lacks sufficient documentation or is not sufficiently compartmentalised. While it is usually possible to interface with code in other languages, *Gamera* tended to avoid doing this in order to keep the tool chain as minimal as possible and to minimise overheads.

Code that is not sufficiently compartmentalised is perhaps the negative side of wanting never to reinvent the wheel. It can sometimes depend on too many other components to be reasonably borrowed without introducing a prohibitive maintenance overhead. This is not a problem when sticking to delineated environments (for example, *KDE* or *MS-Windows*), where certain libraries can be expected to become available. However, in cross-platform development, things become more varied. *Gamera* includes a number of third-party dependencies as part of its distribution. This reduces maintenance and distribution problems, though the flipside is that it does not scale well. *Gamera* uses Open Source libraries for image file formats (*libtiff* and *libpng*), image processing (*VIGRA* and *Xite*), genetic algorithms (*Galib*) and cross-platform GUI development (*wxWidgets*, formerly known as *wxWindows*). The *Python* programming language is a fundamental component, and *Gamera* has returned the favour by contributing improvements to the *Python* project.

Gamera's Chief Developer Michael Droettboom views source code as a precise form of academic communication, acting as a complement to published papers: "Sharing source code," he says, "is an increasingly important part of academic discourse." Droettboom would like to see more source code distributed with papers, believing that this can be a more precise way of communicating expertise. As a new generation of programmers enters academia, many having learned programming languages concurrently with natural language, source code could become an important "mother tongue" for technical communication.

Open Source's community-based approach had a major impact on Gamera, indeed the project's development can be divided into two phases: before and after its release on *SourceForge*. In the first phase, the bulk of the development was done by two peer-developers working in the same room, and about a year into the project much of the code was scrapped and rewritten in favour of a wholly new design.[120] In the *SourceForge*-based phase, the development model became more hierarchical, with Droettboom's role moving

120 This fits in with the "be ready to start over *at least* once" maxim of Eric S. Raymond in *The Cathedral and the Bazaar* (O'Reilly 2001, pp. 25.)

more towards that of the coordinator of student employees and mailing list contributors. Most of the code is still written in-house, but outside help comes with finding bugs and solutions, with building and porting issues, and occasionally with the contribution of entirely new features. The order in which new features are added is now determined more often by popular demand than by personal interest. While **DKC** often solicits and considers feedback from outside developers and users, it still maintains the final say as to where the 'official' *Gamera* will go. However, document image analysis is a rich field and impossible for one person to digest in full, so there will always be a need for external expertise.

Encouraging developers who are not already producing Open Source code to do so has been difficult, as many programmers, at least within academia, seem embarrassed by the quality of their code and fear public ridicule.[121] It was also found difficult at first to foster collaboration on the mailing list due to perceived misunderstandings about *Gamera*'s real purpose. Within a few weeks of having the mailing list, a strong community of skilled people has emerged, and things are improving. One of the best things about archived mailing lists is that new members can easily come up to speed on all of the hard-earned knowledge of others before them. It should also be noted that some of the list's most active members use *Gamera* as part of their job or studies and are not simply hobbyists. This is likely to contribute to their level of participation.

The Gamera console

© Gamera

Experiments have been conducted on the mailing list in order to seek advice about outstanding problems with the system. *Gamera* has been successful on a small scale locally and to a number of outside developers creating symbolic representations, although Droettboom admits that there is still some way to go before the goal of making it more accessible to less technically-literate users is achieved. This will require more work in examining the generalities of *Gamera*-based systems and making them easier to use. It will also require some progress in some of the Open Source tools on which *Gamera* is built, such as *Python* and *wxWidgets*.

In the future, *Gamera* will continue to develop by being used and put into production behind real systems. It is hoped that it will, at reasonable cost, enable the creation of symbolic representations of cultural heritage materials that may otherwise fall deeper into obscurity in the all-digital future. Indeed, this is how the team would like *Gamera*'s success to be judged. The ultimate goal of the data that a *Gamera*-based system produces is to keep access to cultural heritage materials in line with the increasingly high expectations and demands of consumers. While the original team may not be able to maintain *Gamera* indefinitely, with the source code available, anyone with sufficient vested interest could do so. This certainly cannot always be claimed for proprietary systems.

121 Droettboom: "As an aside, that sort of blunt criticism is something I've come to expect since the release of Gamera, particularly at the beginning when many bugs were found in quick succession. That feedback, however, has been incredibly valuable in making Gamera more robust and usable. However, this may come at the expense of losing some early adopters who were frustrated with earlier versions. The 'when to release' question is definitely an important trade-off to consider, though one which can probably never be adequately answered."

Scenarios

Using Open Source and standards for a musician's Web archive

Jed Walkins is an established and artistically successful country singer who first came to prominence in the late 1930s and among fans and critics is regarded as one of the original pioneers of the celebrated 'bluegrass' sound. Following a long, creatively rich career spanning seven decades, Walkins wishes to make his extensive body of work available for free or little cost as an expression of his long-held belief in the importance of free and unmetered access by all to the fruits of human creativity. His output has included some of popular music's most cherished, thoughtful, politically insightful and inventive material. The public benefits from opening up these culturally and sociologically profound resources are indisputable. Walkins wishes to encourage people to copy, redistribute, build upon and seek understanding of every part of his work, and regards it as a key goal to remove any barriers or sense of mythology from his art.

Walkins' body of work comprises a number of different media types, including sound recordings, printed and handwritten lyrics, musical notation, artwork, promotional materials, poems, musings and sketches. Having been informed of a number of successful existing Web-based artist archives,[122] Walkins decided to commission the construction of a Web-based repository of his own. Throughout his career, he has maintained and made evident through his songs a staunch moral political stance and is famously distrustful of corporate and financially motivated institutions and infrastructures. It is a key requirement in the development of his Web archive that his politics are not undermined or contradicted. As well as this it is important that the established archive offers good performance, and is suitably scalable so that gradually more and more materials can be added. Cost is also an inevitable factor, and it is hoped that a solution can be reached without spending too much money. Ideally there will be no costs that need to be passed on to online visitors or paid for through advertising agreements.

It is decided that Open Source Technologies can be effectively utilised and combined to ensure that all of Walkins' requirements are comfortably met. Because Open Source software is freely available and more associated with solving problems effectively than with making money, its use sits well with the political sentiments often expressed by Walkins' in his music and interviews. Indeed, close parallels can be identified between Walkins' intention to make his work available for free without limitation with that of the Open Source Community, which encourages copying, redistribution and reuse of software. Using a combination of the *GNU/Linux* operating system, the *Apache Web* server, the *MySQL* relational database management system and the *PHP, Python* or *Perl* programming languages a Web archive can be created from scratch, with no software costs and no restrictive software licenses. Alternatively, existing Open Source content management tools such as *Plone* or *XOOPS* can be used to structure, manage and present Web based materials straightforwardly.

Open Source will play a key role in the materials being presented as well as at an infrastructure level. Only by choosing Open Source formats can the opportunity to access these materials become truly universal. Proprietary formats invariably require proprietary

122 For a real-world example along similar lines see the **Woody Guthrie Foundation and Archive** at http://www.woodyguthrie.org

viewing or playback software and this undermines accessibility. All static visual materials such as lyrics, musical notation, artwork and promotional materials can be encoded into the *Portable Document Format* (PDF), an open format that is very popular on the Web and is supported by a number of viewer applications, most notably Adobe's *Acrobat Reader*.

In addition, any other images could be presented in the *Portable Network Graphics* (PNG) image format which offers compressed or uncompressed images compatible with most Web browsers. Unlike formats like GIF, it is not restricted by patents. Sound recordings can be made available using the compressed *Ogg Vorbis* format, which offers file size and sound quality comparable with the proprietary, license-fee payable MP3 format. Numerous freeware or Open Source players are available to play back *Ogg Vorbis* encoded music. These technologies are all mature and widely used, and offer performance commensurate with or in many cases in excess of their proprietary peers. None represent preservation or archival formats, although this is simply due to the nature of this particular project which has mainly presentational goals. Open archival formats are also available.

The final result of the Walkins archive will have a participatory element, allowing visitors to submit their own stories and experiences of Walkins' work, of their own performances of his material and any other relevant content that would be at home within the established framework. These would themselves then form part of the browsable content of the archive, another aspect of the functionality facilitated by the use of the Open Source tools.

Making the switch from proprietary to Open Source software

A non-profit museum with the self-imposed remit to preserve and make available to the public materials documenting the performing arts is looking to rethink its ICT policy and infrastructure in order to obtain better value for money. The financial model upon which the institution is built is essentially hand to mouth, with a small supplementary income from grants and from donations which are encouraged from visiting guests and local patrons. The most significant portion of these monies is spent on the salaries of three full-time and a further two part-time worke rs who share curatorial, administration and customer service duties.

The institution has several basic ICT needs, which are currently met using a combination of in-house proprietary software and externally provided services. A *Windows Small Business Server 2000* machine takes care of intra-office email, virtual private network (VPN), firewall, file and print services. An additional *Windows* machine hosts a **Microsoft** *Access* database containing the collection information. Each of the five desktop workstations within the museum's office and foyer is installed with *Windows 98 Second Edition* with **Microsoft** *Office 97* for basic productivity tasks (word processing, spreadsheets and presentations). XYZ Web Services, an external hosting company, offers Internet, email and Web services for an annual fee, which although not huge could be directed used elsewhere to supplement or improve the institutional collections.

The most significant problem with the existing system relates to the licensing agre ements that govern the use of the in house proprietary software products. Despite having the combination of *Windows* and *Office* installed on five individual workstations, only a single legitimate license has been acquired for each of these two products. Similarly, the main *Small Business Server* software is currently not licensed, having been installed by a staff member using a borrowed CD-ROM, which leaves the institution exposed to a potentially crippling series of fines. Unfortunately, funding restrictions are such that the institution simply cannot afford to purchase the appropriate software licenses, and a recent technology grant application has been unsuccessful. Nonetheless, it is vital for the museum to maintain the numbers of machines in place in order to function effectively. In addition to dealing with the licensing problem, the institution is committed to bringing the Web site and email hosting in-house to conserve further funds. The museum is conscious though that the combination of technologies used by XYZ (**Microsoft**'s *Internet Information Server* Web server and *Exchange* email server) would require the payment of additional license fees to operate.

Since the museum's ICT needs are fairly mainstream, with little or no reliance on particular specialist applications or hardware, a migration to Open Source software is identified as an ideal solution to the inherent problems that accompany and characterize the existing proprietary infrastructure. The institution therefore commits to a move to the *GNU/Linux* Open Source operating system. The **SUSE** *9.1* distribution is chosen since it is well documented, extremely stable, and offers optional commercial support. This operating system replaces *Small Business Server 2000*, and offers file and print services through *SAMBA* to a single existing *Windows* client and native access to the four unlicensed *Windows* machines that will also be converted to *Linux*. All existing (licensed and unlicensed) versions of **Microsoft** *Office* will be replaced by *OpenOffice*, which offers performance and functionality in excess of *Office 97* and is available for both *Windows* and *Linux*. By standardising this application it ensures that documents can be shared throughout the institution more effectively. The majority of legacy data in *Office* formats will continue to be accessible using *OpenOffice*, which can read from and write to *Excel, Word* and *PowerPoint* formats. For the small selection of documents that lose formatting or sense when viewed in the non-**Microsoft** application the single licensed copy of *Office* can be preserved to perform data conversion into a more universal format such as *Rich Text Format* (RTF) or HTML. There may be some additional problems with migrating data that incorporates *Visual Basic for Applications* (VBA) macro functions. Since the Visual Basic runtime is completely closed-source, it has so far not been possible for *OpenOffice* developers to incorporate even stripped down support for VBA macros. However, *OpenOffice* does incorporate its own BASIC scripting language called StarBasic which, while syntactically different from **Microsoft**'s implementation, incorporates sufficient flexibility to straightforwardly port most existing VBA code to the *OpenOffice* platform. If it is decided subsequently that a heterogeneous network is unnecessarily complex, the final *Windows* license can be abandoned or utilised on a machine elsewhere in favour of standardised *Linux*.

The free *qmail* email server and the *Apache Web* server can be installed on a single *Linux* server to offer the museum Internet email and the ability to serve its own Web pages internally. The existing database content can be straightforwardly exported and moved to a *PostgreSQL* database, an Open Source product that offers excellent performance, support structures and documentation. This can be straightforwardly installed on the primary *GNU/Linux* server in addition to the other services, freeing up the previously dedicated database machine which can then be used as a dedicated firewall/network security server. The **Astaro** *Linux Security* product can be installed on the server to offer firewall, virtual private network (VPN) and network security.[123] Although this is not free software, costing around €390, it is the only software acquisition cost that will have to be met, representing an excellent total network security solution. It offers a manageable and intuitive interface

123 http://www.astaro.com/

as well as commercial-quality support and documentation. In addition, like *Linux* itself the software is built to run well on even low specification hardware, guaranteeing its shelf life and freeing the museum from the potential future costs inherent in frequent hardware upgrades.

With these changes in place the museum will save around €3000 in software licenses and around €250 per year in subscription costs from the Web hosting company **XYZ**. In addition, the museum will no longer be exposed to the possible unlimited fines and jail terms that using unlicensed products can lead to. The museum will also feel more comfortable in seeking support knowing that there is no chance of being unmasked as a copyright thief. In addition, the museum's machines are now less at risk from viruses and security compromises. More control can be exercised by staff over their own content since they are hosting their materials and services in house and are no longer at the mercy of an external provider.

Why develop an Open Source application? The 'story' of Open-Notate

A frustrated group of University based musicologists and composers has struggled for some time with various proprietary music notation packages such as *Finale* and *Sibelius* which, although perfectly adequate for mainstream music representation, fall sadly short when dealing with the kinds of atypical musical structures that they are interested in rendering. The primary requirement that the group identifies is to have an application that is sufficiently flexible to support the creation of Gregorian Chant musical notation. Following a brief period of investigation, the group has become convinced that no existing package offers its desired functionality, and the group members approach a computer scientist friend to suggest that he undertake the development of an application based on their needs.

It is acknowledged early on that this project could be of benefit to numerous other parties seeking to publish older or non-standard musical pieces and that there is likely to be a significant community of interest because of this. It becomes increasingly clear that, in order to ensure the application can support many different structures, it would be advantageous to seek the input of other interested contributors to ensure that this flexibility is incorporated. The group that originally proposed the application is small and closely related both in terms of its interests and its geography, and it is quickly decided that to open the development to a wider, more diverse forum would be advantageous.

It is also immediately clear that to develop this application single handedly from the ground up is likely to be an incredibly onerous task for the single computer scientist. While there is a wide potential user base that can offer useful contributions in terms of functionality that can be incorporated, there is also a vast Internet-accessible developer base that might be called upon to contribute with code, debugging and documentation. Also, it is identified that there are a number of existing Open Source products and code libraries that could be built upon to facilitate the develop of the notation editor, such as the user interface scripting language combination of *Tcl* and *Tk* and the musical formatting processor/syntax *Lilypond*.

Therefore, it is decided to develop this project as an Open Source Application. The '*Copyleft*' requirements of many open source licenses ensure that they can be reused and integrated with new applications only if the results are then themselves released under the same license. The most obvious advantage is that development need not stall while code that already exists and is available elsewhere is reproduced. A project Web page is quickly published, offering a central point for access to incremental builds of the application for further development, testing and debugging and a discussion forum that will hopefully provide ideas on the features that should be incorporated and direction that development should take. The *Concurrent Versioning System* (CVS) is configured on the Web site, providing developers the ability to concurrently track (and potentially revert) incremental changes to files, reporting them to a mailing list as they are made. The cooperation and involvement of a worldwide Internet-based community will ensure that the final results are more flexible and user-tuned, are achieved more quickly and are less likely to contain bugs. Also, the prominence that the project will take on if successful should ensure its continued development and maintenance, regardless of the availability or inclination of the individual who developed it. Open Source software tends to gain prominence from several different channels. Word of mouth can quickly establish the reputation of a technically-successful project, and this can happen in the physical world or, more commonly and more effectively, through virtual communities, built upon structures such as message boards, discussion fora, instant messaging, *blogs* and *wikis*. This is supported and inspired by a number of Web based centres for Open Source software and development. The most notable example is the **Open Source Developers Network** (OSDN),[124] which represents a dynamic community-driven network consisting of a variety of diverse media. Under its umbrella are the popular news discussion site *Slashdot.org* and the world's largest collaborative Open Source software site *SourceForge.net*.[125]

This shows how a group with no particular technical experience and only limited personal access to technical assistance can identify a software niche and, due to the unique development model that underpins Open Source software, develop an appropriate application to solve the problem.

Open Source and Proprietary Software: A Quantitative Comparison

Introduction

The world of software development and distribution is extremely competitive, and amid an ocean of hyperbole and jargon it is often difficult to identify where the advantages of particular packages, operating systems and applications truly lie. This is a particular challenge when seeking hard, quantitative, comparative data about the merits of one approach over another. Nonetheless, it is important to consider these issues. It is worth bearing in mind that numbers rarely tell the whole story, and the non-quantitative advantages already outlined may be equally or more convincing.[126]

124 http://www.osdn.com
125 http://www.slashdot.org; http://www.sourceforge.net
126 David A Wheeler offers an impartial and detailed account of the various quantitative issues relating to Open Source and Proprietary alternatives in his article "Why Open Source Software / Free Software (OSS/FS)? Look at the Numbers!" http://www.dwheeler.com/oss_fs_why.html

Total Cost of Ownership

It is important to consider a product's financial implications in terms of total cost of ownership (TCO), particularly when it is given away free of charge. However, since a definitive list of the cost factors that should be taken into account in a TCO study has yet to be settled upon, a number of conflicting accounts exist. It is quite possible to identify for every mainstream operating system a study that 'proves' it has the lowest TCO, but the actual figures will always depend on a combination of environment and requirements. An accurate picture can only be drawn following consideration of all relevant individual cost elements, from software purchases to administration, from technical support to hardware and training.

The initial acquisition cost of Open Source software will usually be less than any proprietary alternative. Of course, it need not be free (i.e. *gratis*) under the terms of its license, and other additional costs may be incurred through documentation, storage media, and training courses. Taking these factors into account, a 2001 study by **Cybersource Consulting** found the following acquisition cost results, illustrating the scalability of an Open Source solution over three increasingly sized installation environments:[127]

	Microsoft	OSS/FS *(GNU/Linux)*	OS Savings
Company A (50 users)	$69,987 (€56,615)	$80 (€65)	$69,907 (€56,550)
Company B (100 users)	$136,734 (€110,609)	$80 (€65)	$136,654 (€110,544)
Company C (250 users)	$282,974 (€228,907)	$80 (€65)	$282,894 (€228,842)

The reason why Open Source software scales so well is that it is usually only necessary to purchase a single license, which covers unlimited subsequent installations. Proprietary software, on the other hand, is typically licensed on a per-machine basis. This is worth bearing in mind if the intention is to deploy a large number of workstations. ***Network World Fusion News*** reported in 2001 that a major part of the reason for a major increase in *Linux*'s deployment in finance, healthcare, banking and retail was its scalability in cost and technical terms when large numbers of identical sites and servers are needed. The journal calculated that for a 2,000-site deployment ***SCO*** *UnixWare* would cost $9 million (€7.3m), *Windows* $8m (€6.5m), and **Red Hat** *Linux* just $180 (€146m).[128]

Upgrade costs also compare favourably using Open Source applications. Proprietary upgrades will typically cost around half the amount of the original application. Users can subsequently find themselves at the mercy of the proprietary companies, who have a monopoly on the distribution of their software. To upgrade an Open Source application one simply has to download the latest version, or pay the original cost once again and redeploy across as many machines as required.

Open Source software looks favourable once again when one considers the issues of license management and litigation. For users of proprietary software, failure to adhere to the strict terms of their software licenses can lead to extremely heavy fines and even custodial sentences. It is therefore in users interests to manage licenses effectively, undertaking regular software audits and perhaps installing license-tracking software. Under an

127 http://www.cyber.com.au/cyber/about/linux_vs_windows_tco_comparison.pdf
128 http://www.nwfusion.com/news/2001/0319specialfocus.html

Open Source license such procedures, costly in terms of both time and money, are rendered unnecessary.

As far as hardware is concerned, it is generally acknowledged that Open Source software – such as the *GNU/Linux* operating system – can run effectively on a lower specification machine than its *Windows* equivalent. The latest version of *Windows, XP Professional*, recommends a 300Ghz processor, 128MB of RAM and a minimum of 1.5GB of hard disc space. **Mandrake**'s *Linux* version 9.1 will happily run with any Pentium class processor, 128MB of RAM and just 150MB of disc space. As *Linux* desktops and user interfaces have become more graphically challenging the margin between the two has narrowed. But since a *Linux* system tends to be generally configurable, it is more straightforward to install only those parts of a system that are really required, saving processor power and disc space.[129]

For other less quantifiable aspects of cost it becomes more difficult to find consensus. Technical support and administration is one such area. **Microsoft** claims that it is more straightforward to find trained administrators and technicians for its platforms, and that they therefore cost less. However, the Open Source community rebuts this, arguing that with *GNU/Linux* fewer administrators are required, because it is possible to automate a great deal and the systems are more reliable.

A further question is that of training. Anecdotal evidence suggests that the costs involved are fairly modest, thanks to the proliferation of modern GUI desktops within *Linux* systems. It remains to be seen whether this is demonstrably true across the board, although it could be argued that training costs should be no more than those incurred for *Windows* training. However, *re*training experienced *Windows* users will inevitably be more challenging, involving higher associated costs.

The **Robert Frances Group**'s July 2002 study found that the TCO of *GNU/Linux* is roughly 40% of that of *Windows*, and only 14% of **Sun Microsystems**' *Solaris*.[130] The group used actual costs of production deployments of Web servers at fourteen **Global 2000** enterprises, basing its analysis on software, and hardware purchases and maintenance, upgrade and administrative costs. This study also found that although *Windows* administrators cost less individually, each *Linux* or *Solaris* administrator could cover many more machines, making *Windows* administration more expensive. It was also revealed that Windows administrators spent twice as much time patching systems and dealing with security issues than the others.

There is also a great deal of persuasive testimonial evidence from a range of companies and public institutions that have used Open Source successfully and saved money. For instance, **Amazon.com** was able to cut US$17m (€13.8m) in technology expenses in a single quarter by moving to *Linux*. The city of Largo in Florida saved $1m (€811,000) by using *GNU/Linux* and 'thin clients,' and **Intel** Vice President Doug Busch reported savings of $200m (€162.4m) by replacing proprietary *UNIX* servers with *GNU/Linux* alternatives.[131] While TCO studies are useful for interest purposes, the source of their commissioning should be carefully noted. At least one **Microsoft** sponsored study has suggested that *Windows* is cheaper than *Linux*,[132] although technology writer Joe Barr has discussed and criticised some of the problems inherent in the report, such as assuming no

129 This also means that hardware can be used for longer, without the need to upgrade so frequently.
130 Reported on http://www.dwheeler.com/oss_fs_why.html
131 http://techupdate.zdnet.com/techupdate/stories/main/0,14179,2860180,00.html; http://www.dwheeler.com/oss_fs_why.html; http://news.com.com/2100-1001 275155.html?legacy=cnet&tag=owv
132 http://www.microsoft.com/windows2000/docs/TCO.pdf

upgrades over a five year period, costing for an older operating system, and not using the current **Microsoft** *Enterprise* license. Barr concludes his report by stating that "TCO is like fine wine: it doesn't travel well. What may be true in one situation is reversed in another. What gets trumpeted as a universal truth ('*Windows* is cheaper than *Linux*') may or may not be true in a specific case, but it is most certainly false when claimed universally."[133]

Performance and Reliability

As far as performance and reliability are concerned, further empirical evidence suggests that Open Source technologies compare favourably with their proprietary peers. According to a study undertaken at the **University of Wisconsin** in 2000, 21% of *Windows* 2000 applications crashed when presented with random testing using valid keyboard and mouse input.[134] An additional 24% of applications hung when presented with valid keyboard and mouse input. When the same test was undertaken five years earlier using the then current *Linux* distribution, the failure rate was just 9%; and since then the reliability of Open Source software has improved. Comparable studies by **IBM, ZDNet**, and **Bloor Research** have had similar results.[135]

An e**Week** survey in 2002 found that *MySQL* was comparable to the proprietary market leader, *Oracle*, and offered better performance than a number of other proprietary applications, including **Sybase Inc**'s *ASE*, **IBM**'s *DB2* and **Microsoft**'s *SQL Server 2000 Enterprise Edition*.[136]

As far as performance is concerned, the results for Open Source are also promising. As with TCO, performance benchmarks are often dependent on environment, as well as whatever assumptions the tester has made; the only real benchmark that can be of value to an individual user is the one that most closely mirrors the work actually being done. **PC Magazine** found in November 2001 that *Linux* with *SAMBA* significantly outperformed *Windows* 2000. At one stage in the test, using a 1Ghz Pentium 3 with 512MB of RAM and handling thirty client connections, the *Linux* software was 78% faster than **Microsoft**'s.[137] In February 2003, a team of physicists broke the Internet2 Land Speed Record using *GNU/Linux*, sending 6.7GB of uncompressed data from Sunnyvale California to Amsterdam in just 58 seconds.[138]

Market Share

Serving Web pages is one area where Open Source already leads the field. According to **Netcraft**'s statistics on Web Servers the *Apache* Web server served approximately 67% of all Web pages in July 2004, with the closest rival **Microsoft**'s Internet Information Server responsible for 21%. *GNU/Linux* is the second most prevalent operating system

133 Reported on http://www.dwheeler.com/oss_fs_why.html
134 ftp://ftp.cs.wisc.edu/paradyn/technical_papers/fuzz-nt.pdf
135 http://www-106.ibm.com/developerworks/linux/library/l-rel/;
http://Web.archive.org/Web/20010602081713/www.zdnet.com/sp/stories/issue/0,4537,2387282,00.html;
http://gnet.dhs.org/stories/bloor.php3
136 http://www.eweek.com/article2/0,3959,293,00.asp
137 http://www.pcmag.com/article2/0,1759,16227,00.asp
138 http://www.wired.com/news/infostructure/0,1377,57625,00.html

for Web servers with 29%, behind *Windows* which has just under half of the entire market share. Other Open Source operating systems comprise around 6% of all those that serve Web pages.[139]

Open Source software enjoys prominence in other areas of the Internet too. *Sendmail* is the leading email server, with 42% of the market share.[140] *Bind*, an application that translates human-readable Web site names into a format understandable by computers, had a 95% market share in 2000.[141] *PHP* is the most commonly used Web programming language in the world, running on over sixteen million sites during June 2004, outstripping its primary rivals *ASP.NET, Java Server Pages*, and *Cold Fusion*.[142]

At a more general level, part of the findings of the Free/Libre and Open Source Software (FLOSS): Survey and Study published in June 2002 found that 43.7% of German establishments, 31.5% of British establishments, and 17.7% of Swedish establishments reported using Open Source or Free Software.[143] Open Source is well established within the infrastructure of the Internet, but it is only in relatively recent times that appropriate software has become available to make *Linux* a viable choice for desktop computer users. Improvements in graphical user interfaces (GUIs) and the potential to use *Linux* without recourse to unfamiliar command line instructions have made it an attractive prospect for the casual, non-expert user. A number of institutions, companies and organisations are planning or beginning migration. Public sector institutions, with strong requirements for digital preservation and for being able to dictate their own terms for software use are understandably among the most keen.

Licensing Issues - the SCO Question

In recent months a legal contest has developed between the Open Source movement and the **SCO** group, which claims to own the intellectual property rights to the UNIX operating system, alleging that developers have illegally used sections of UNIX code within *Linux*.[144] **SCO** has directed much of the blame towards **IBM**, which is responsible for a great deal of *Linux* development, and have insisted that every *Linux* user pay a license fee for its use or face legal redress. Various claims and counter claims have subsequently arisen and **SCO** now finds itself locked in legal battles with **IBM, Red Hat** (the leading US *Linux* distributor), and two prominent *Linux* users: **Daimler-Chrysler** and **AutoZone**. A further claim against **Novell Inc.** relates to a contention that when **Novell** sold the *Unix* business to **SCO** in 1996, no transfer of copyrights actually took place. If this is found to be true then **SCO** has no intellectual property rights to protect.

Writing in *Wired.com*, Brad Stone offers some insights into the legal challenges facing **SCO**:

> **SCO** must show that the old, murky contracts between AT&T (which developed *Unix*), Novell (which bought the operating system from AT&T in 1993), and the old Santa Cruz Operation deliberately transferred the Unix copyrights to the new

139 http://news.netcraft.com/
140 http://cr.yp.to/surveys/smtpsoftware6.txt
141 http://www.isi.edu/~bmanning/in-addr-versions.html
142 http://www.php.net/usage.php
143 http://www.infonomics.nl/FLOSS/
144 http://www.sco.com

> **SCO** Group; it also must show that it owns the rights to derivative flavors of Unix, like IBM's *AIX*. Finally, and perhaps most difficult, **SCO** must prove IBM and other *Linux* programmers around the world got sloppy and ported proprietary code into *Linux*. Legal experts tracking the case think each hurdle - let alone all three - is difficult to clear. The odds are clearly against **SCO**.[145]

The issue is something of a legal minefield, although most prominent Open Source affiliated and neutral technologists seem to think that the courts will immediately dismiss **SCO**'s claims. Even if **SCO** were to win then Open Source would continue – the offending parts of the *Linux* code would simply be rewritten and the process would re-emphasise the strength of the Open Source community. However, there remain some nervous *Linux* users, illustrated by the fact that several companies have already paid **SCO**'s fee to avoid the threat of challenge in the courts. For most *Linux* users though, the consequences need not be regarded as particularly significant. **Novell** Inc. and **Hewlett-Packard Co.** already provide, at no charge, indemnifications to their *Linux* customers, and **Red Hat Inc.** promise to replace any infringing version of *Linux* with a non-infringing version. In addition, the first company publicly revealed to have bowed to **SCO**'s demands, **Everyones Internet Ltd**, has been reported as having regretted its early decision to do so, with CEO Robert Marsh admitting, "Would I do it again? No. I'll go on the record as saying that… I certainly know a lot more today than I knew a month ago, in a lot of respects."[146] It is unclear what proportion of these regrets are directly attributable to the vilification that has been directed towards **EIL** since they elected to associate themselves with the "*Linux* community's number one enemy."

Many writers contend that it is Linus Torvalds, the originator of *Linux* who should carry the lion's share of the blame for these events. Because of poor documentation, details of who wrote what part of the operating system (and consequently who owns it) are somewhat unclear. Unlike *GNU*, which at Richard Stallman's insistence made contributors sign over their copyrights to the project, *Linux* was developed in a more *ad hoc* fashion, and Torvalds never anticipated that it would become the centre of a multi-billion dollar business. Lessons have been learned though, and in May 2004 the newly formed **Open Source Development Lab** announced that future *Linux* code submissions would require accompanying documentation detailing their ownership and verifying the Open Source license under which they were made available.[147]

145 http://www.wired.com/wired/archive/12.07/linux.html?pg=4&topic=linux&topic_set=(none)
146 http://www.computerworld.com/governmenttopics/government/legalissues/story/0,10801,91671,00.html; http://my.ev1.net/
147 http://www.osdl.org/

Introducing the Technology

Technological issues

The adoption of Open Source technology need not be revolutionary, and migration to free software tools can be undertaken at a range of levels from individual applications to an entire IT system infrastructure. Since a range of Open Source tools are available for mainstream operating systems, it is not necessary for staff to discard the skills developed through long-term familiarity with proprietary applications. Part of the appeal of Open Source tools is that by virtue of their transparent nature it is possible to integrate their use within existing heterogeneous environments straightforwardly, and with none of the restrictions traditionally implemented by proprietary developers seeking to create software dependency.

Migration Issues

There will be a range of issues to consider if the decision is made to move from proprietary technologies to Open Source alternatives. Planning is essential if the proposed migration is to be a success and must take management, administration, human resources and technical considerations into account. The EC-commissioned 'Integration of Data between Administrations Open Source Migration Guidelines'[148] detail in great depth the vast array of issues involved and are an important source for any IT administrator.[149] Extensive details of applications are presented, with insights into which Open Source packages could best replace each individual proprietary tool commonly in use. It is worth bearing in mind that 'Big Bang'-style migrations, where the change is to be implemented in a very short timescale, are notoriously prone to failure. Because a great deal of the most successful and mature Open Source applications are available for a number of platforms, it may be advantageous to introduce applications such as *OpenOffice, Mozilla, Apache* and *MySQL* gradually and within a familiar environment before subsequently migrating to an open operating system. The *OpenCD*,[150] which collects a variety of Open Source applications on a single disc, is particularly useful for straightforwardly deploying and integrating Open Source tools within a *Windows* environment. Alternatively, projects like *Knoppix Linux* and the **SUSE** *Live-CD* allow users to insert a CD-ROM, reboot, and run Linux from the disc without touching any existing *Windows* installation; this is a quick, clean and painless way of trying out the system.[151]

Data migration issues can be more complicated; hardly surprising considering the fact that the "closedness" and inaccessibility of proprietary formats often motivate a change to Open Source. The IDA guidelines again offer valuable insights here, detailing several scenarios in which the migration procedure is explained step-by-step. Migrations from Internet Information Server to *Apache*, from *Access* to *MySQL* or *PostgreSQL*, and from

148 Prepared by *netproject*, and available from http://www.netproject.com/docs/migoss/v1.0/
149 Another worthwhile reference is the Web site http://www.linuxmigration.com/
150 http://www.theopencd.org
151 http://www.knoppix.org/; http://www.SUSE.de/en/

Microsoft *Office* to *OpenOffice* are all covered in detail.

Any adoption of Open Source tools will inevitably result in some disruption, but there is a range of ways in which this can be mitigated depending on the nature of an institution's process. The following paragraphs suggest some typical migration scenarios, describing the issues that must be anticipated in each instance.

Application Level Migration

Under these circumstances, an institution running several *Windows* desktop PCs may decide to replace a range of proprietary software tools with Open Source equivalents. Examples may be swapping *OpenOffice* for **Microsoft** *Office*, *Mozilla* for *Internet Explorer*, and the *GIMP* for *Photoshop*. Highlighting advantages such as decreased cost, increased security and a greater level of usability, the institution will be interested in achieving the smoothest possible transition. Since a number of the most significant and useful Open Source programs are available for both free and proprietary Operating Systems, an institution can retain its existing infrastructure, simply installing the appropriate applications for *Windows*. This is a common precursor to a system-wide move and offers a phased migration to a global Open Source environment. Inherent differences between individual applications will require some degree of personal (if not necessarily financial) investment in retraining, but this ought not to be too onerous as the tools mentioned above behave similarly to those of their proprietary equivalents. More significant are the potential problems with file formats in terms of compatibility with existing resources and services. Migration to *OpenOffice* will hopefully follow a system-wide decision to encode documents in open formats, but legacy data in **Microsoft** formats, particularly any containing *Visual Basic for Applications (VBA)* code may suffer information loss when viewed and edited within *OpenOffice*. The solution here is to implement a policy of data migration to open formats like *Rich Text Format (RTF)*, with especially high priority given to documents containing more complex structures such as embedded objects or complicated tables. Further issues may arise with **Microsoft** *Access* databases, which are unsupported by *OpenOffice*. The solution here is to export these into an alternative format, such as a spreadsheet, formatted text file, or straight SQL, which can then be imported into a *MySQL* or *PostgreSQL* database. Problems with some Web sites which do not correspond to the appropriate standards may mean that performance or accessibility is impaired when using a non-*Internet Explorer (IE)* browser. Some **Microsoft** Web-based services (such as the automated *Windows Update* tool) implicitly require *IE*. But such problems are increasingly rare, and since *IE* remains an integral part of the *Windows* package it is always available to use. Image editing packages sometimes utilise bespoke formats for image creation and editing prior to export, but the *GIMP* supports over thirty formats including **Adobe**'s proprietary *Photoshop Document (PSD)* format. In terms of availability, most Open Source applications can be downloaded from the Web, although to an extent this presupposes the availability of broadband Internet access. Applications tend to be quite large and downloading over a 56K connection would take some time.

Partial System Level Migration

It is common for institutions to continue to use existing proprietary software in their desktop environments, but to migrating their network services to Open Source. In such a case, the need for reliable expertise increases, although staff-wide training is not a priority since an experienced system administrator should be able to reproduce existing system functionality with desktop users unaware of the switch. Sample installations are the *GNU/Linux* Operating System, *Apache* Web-server and *Sendmail* email server replacing existing *Windows* Operating System and Server software. The popular *SAMBA* server could also be utilised, allowing *Windows* clients to access file and print sharing services on a *GNU/Linux* host.

Full System Migration

If the decision is taken to migrate an entire IT infrastructure to Open Source, all of the above issues must be considered. There are additional consequences to the complete removal of proprietary software solutions. The biggest problem is likely to be that of application availability. While the depth and breadth of Open Source applications is undoubtedly large, there inevitably remain some specialist programs that are available only under a proprietary software license. It could be that these applications are required within the institution, or that other institutions expected to be able to exchange data encoded in their proprietary file formats. A number of solutions exist, including emulation-style tools such as *WINE* and *Crossover Office*, VMware-style tools that allow a virtual *Windows* machine to be installed and run within *Linux*, and multi-booting configurations whereby two Operating Systems (usually *Windows* and *GNU/Linux*) are installed on a single machine. Each option has its own problems. If licensing costs are a significant factor in a move away from proprietary tools, neither virtual machines nor multi-booting may appeal since both require the purchase of a license for the proprietary operating system. The emulation approach is better from that point of view, but is not completely reliable; even commercial tools like *CrossOver office* are only guaranteed to work with a handful of *Windows* applications, usually mainstream programs with existing Open Source alternatives. It is specialist tools that are least likely to be available under Open Source licenses. This then remains a problem, but it is abating gradually as Open Source developers turn their attention to more specialist tasks, and projects like *WINE* continue to refine and develop their emulation in order to support an increasingly wide range of applications.

Staff and implementation issues

To introduce Open Source technology effectively at any level, it is important that the appropriate stance is assumed across the entire institution. Individuals or groups should be charged (perhaps informally) with keeping track of the latest Open Source developments, identifying new versions of existing tools, and evaluating emerging solutions. This can be done simply by keeping track of a handful of Open Source Web sites, such as **Slashdot, SourceForge** and the **Open Source Development Network**. A commitment to Open Standards should be maintained in order to ensure the straightforward migration to open tools in the future.

While proprietary software advocates often contend that Open Source represents a difficult solution made the more so by the absence of extensive support systems, this is not really so. In fact, *Windows*, **Macintosh**, *Linux* and most *Unix* distributions offer their own challenges and facilitators. Retraining users to adapt to new systems, of course, will require time and resources. Depending on the existing state of an institution's IT infrastructure and requirements, a migration to Open Source need not be overly onerous. Notwithstanding the inevitable retraining issues – applicable only to the first generation of staff after the migration – the problems mainly lie with data re-purposing and the lack of availability of some highly specialised tools. Neither represents a sufficiently significant stumbling block to rule out a move to Open Source at least on some level. Trying Open Source applications is free of charge, and most users are pleasantly surprised by the enhanced functionality and reliability offered by leading applications such as *OpenOffice* and *Mozilla Firefox*.

NATURAL LANGUAGE PROCESSING

Executive Summary

It never is entirely obvious what another who knows it imperfectly is trying say in one's own language: "meaning" rarely enough is obvious even among native-speakers, let alone among those of us who learn another's language imperfectly and only in school or at college or even later on in life.

Translation at least pretends to ease the communication process. To someone French struggling with the meaning of an American phrase such as, say, "pre-emptive strike" – or to someone in the US attempting to figure out a French term such as, say, "force de frappe" – it can be reassuring to have a rendering of terms and explanations in one's own native language to turn to. Assuming, that is, that the rendering is correct… and that it explains policy nuances, and context, and subtleties, and history…[152]

In the article quoted above, Jack Kessler identifies and addresses a crucial problem with modern communications, i.e. being understood. In the modern age, the "fuzzy although entertaining areas" of irony and double entendre extend into politics and diplomacy. And things become dangerous.

Natural Language Processing (NLP) is a catchall term covering a range of related technologies each of which deals in its own way with the questions of understanding and communication. These technologies include:

- *Computational Linguistics and Text Mining* (which covers the extraction and formatting of information from unstructured text – also known as 'parsing'),[153]
- *Conversational Dialogue Systems* (which can be used for customer services, and making merchandising recommendations in e-commerce);
- *Human Language Technologies* (including speech recognition, voice pattern verification, and text-to-speech conversion);
- *Automatic Language Translation, Text Analysis and Knowledge Mining* (including XML-assisted concept extraction), and
- *Text Analysis and Language Engineering* (covering browsing, querying, and summarisation).[154]

The aim of NLP is to allow computers to understand (or 'parse') the meaning of ordinary language and to

152 From Jack Kessler, 'Translating the French…' in *FYI France e-journal*, July 15th 2004. http://www.fyifrance5.com/Fyarch/fy040715.htm
153 See also "Finding Names with the Autonom Parser" in *DigiCULT.Info*, Issue 6, December 2003, pp. 47. http://www.digicult.info/pages/newsletter.php
154 Of course, there are areas of natural overlap between these categories, and it should be obvious this report cannot hope to cover all of them: as with Information Retrieval, below, we cover chiefly those areas that most merit our focus.

perform tasks based on this. An NLP system should be able not only to convert spoken words into text but also to convert the linguistic meaning of the sentence into a form it can understand and perform actions based on it. Many factors contribute to the complexity of this task including the existence of idioms and non-standard vocabulary, words which sound identical but have different spellings or meanings, and the fact that the majority of human communication is non-verbal. At present, NLP works best in restricted circumstances with set vocabularies.

The technology is constantly progressing and each year brings new developments in the market. We use the word 'market' advisedly, for NLP will be worth huge amounts of money when the various technologies reach sufficient maturity. It is difficult to think of a sector that will not have a strong interest in NLP technologies. Because NLP is such big business, there is no shortage of support from large IT and communications corporations such as **IBM** and **BT** and much explanatory and background material is available from these developers on the Web. A key operational goal for both is multilingualism and, in particular, machine-automated, real-time translation between languages.

NLP has strong links with Information Retrieval, Text Retrieval and Document Retrieval each of which depends on establishing a link or relationship between document content and the needs of users. The ways in which users express these needs are crucial since users are unlikely to understand the processes at work in a retrieval system and, therefore, may not express themselves clearly enough or in sufficient detail. **Gartner** reckons that more than 95% of human-to-computer information input will involve textual language by 2012. It should be clear that this topic will be crucial as computers become more people-friendly and their means of operation more intuitive.[155]

HLTCentral is the EU's "Gateway to Speech and Language Technology Opportunities on the Web".[156] Two projects form the basis of *HLTCentral*: **EUROMAP** and **ELSNET**. **EUROMAP** aims to provide awareness, bridge-building and market-enabling services for accelerating the rate of technology transfer and market take-up of the results of European *HLT RTD* projects. **ELSNET** ("The European Network of Excellence in Human Language Technologies") aims to bring together the key players in language and speech technology, both in industry and in academia, and to encourage interdisciplinary co-operation through a variety of events and services.[157]

The case studies and scenarios featured in this section cover a range of NLP deployments from the automatic subtitling of *MUSA* to the user-friendly personalisation service of *M-PIRO* via newspapers, guestbooks and handheld devices. This area will be vital for an increasingly communicative European sector and its uses and benefits become more apparent with every month.

155 Votsch V., A. Linden (2000), "Do You Know What 'Personalization' Means?" Gartner Research ID Number: T-10-9346.

156 http://www.hltcentral.org/htmlengine.shtml?id=615

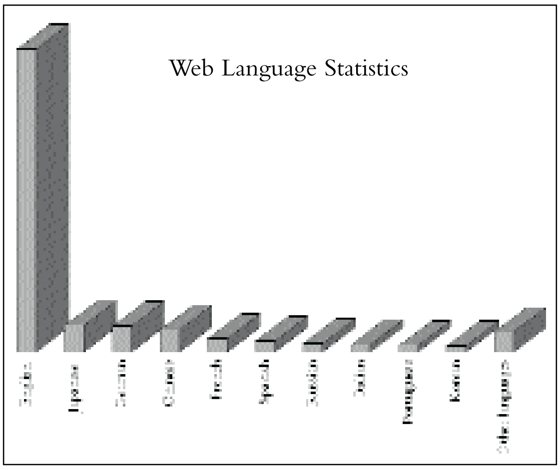
157 See "HLT in Europe: The EUROMAP Language Technologies Project" in *DigiCULT.Info*, Issue 5, October 2003, pp. 15. http://www.digicult.info/pages/newsletter.php

Introduction to Natural Language Processing

Informational Background

The School of Information Management and Systems at the **University of California at Berkeley** estimates the amount of new information produced in 2002 at about five exabytes.[158] Ninety two percent of this is estimated to be stored on magnetic media, and 0.01% on paper.[159] To put these amounts in context, the authors suggest that the **Library of Congress** print collections contain around ten terabytes[160] of information; five exabytes would equal half a million libraries of this size.

The World Wide Web grows constantly, as does the number of its users. English is the most prevalent language, with 68.4% of its searchable content. This is followed by Japanese (5.9%), German (5.8%), Chinese (4.9%), French (3%), Spanish (2.4%), Russian (1.9%), Italian (1.6%), Portuguese (1.4%), Korean (1.3%) and other languages (4.6%).[161]



This leads to several questions: How do people find a specific piece of information quickly without receiving a mass of unwanted material? How can we access resources created in other languages? Can such materials be translated automatically? When will it be possible for all humans to interact with computers using their own languages? How will records be kept of these new transactions? The field which tries to find practical solutions to these questions is Natural Language Processing (NLP).

Natural Language Processing – A Brief History

Natural Language Processing brings together a number of technologies which facilitate tasks involving human-computer interaction, text and document processing, speech recognition and synthesis for access, security and convenience. The set of technologies involved in this area has developed from the dawn of the computer era until the present day. The practical needs which arose, thanks to computer linguistics, have boosted new theoretical developments in the formalisation of languages.

One of the first language-connected tasks for which machines were used was encod-

158 http://www.sims.berkeley.edu/ An exabyte is one billion gigabytes, or 2^{60} (1,152,921,504,606,846,976) bytes.
159 Lyman, P., H.R. Varian (2003) 'How Much Information' http://www.sims.berkeley.edu/how-much-info-2003
160 2^{40} (1,099,511,627,776) bytes.
161 Global Internet Statistics: Sources and References: http://global-reach.biz/globstats/refs.php3

ing and decoding secret messages during the Second World War, with Alan Turing's work on the Enigma code perhaps the most famous example. The development of computers provoked discussions on the level of intelligence computers might achieve. The works of Claude Shannon (1916-2001) on mathematical theory of communications and Noam Chomsky (b. 1928) on transformational grammars were important steps towards a formalisation of linguistic knowledge.[162] Shannon's work influenced the use of statistical methods in the modelling of linguistic phenomena, in active development since the 1970s.

Machine translation methods and tools link the *presentation* and *processing* of linguistic data. The first practical steps towards computer-assisted language processing were taken in the 1950s in the field of machine translation. A number of groups worked on the process making good progress with dependency grammars and parsing but doing less well on translation, which was found to be less accurate, slower and twice as expensive as human translation.[163] Many readers will be familiar with **AltaVista**'s *Babel Fish* online translation service and with the haphazard results it sometimes returns for more complicated sentences.[164]

Machine translation enjoyed a surge in popularity in the mid-1970s prompted by advances in Artificial Intelligence, although practical tasks were restricted to specific subject domains. Since the 1990s, corpus-based machine translation has become a major area. The linguistic rules which dominated practical work in the field were complemented with examples from real-life derived from bilingual or multilingual corpora of parallel texts (the *example-based* approach) or by randomised statistical observations (the *stochastic* approach).

In speech processing, **Bell Laboratories** refined sound spectrograph technology originally conceived in the 1940s by Ralph K. Potter.[165] This facilitated the graphical representation of speech which later became an important tool for work on speech analysis.

Principles of Natural Language Processing[166]

Computational Linguistics

Computational linguistics is "the scientific study of language from a computational perspective."[167] Computational techniques, methods and concepts are used here to present various linguistic phenomena in a formal manner. There are two main approaches: the first is based on formal models with roots in formal linguistics and the work of Chomsky; the second involves the use of large resources – such as corpora (both written and spoken) – and is based on the application of statistical methods.

162 C. E. Shannon (1948), A mathematical theory of communication, *Bell System Technical Journal*, vol. 27, pp. 379-423 and 623-656 (July and October).

163 In 1966, the US Automatic Language Processing Advisory Committee (ALPAC) published a report which reached the conclusion that "there is no immediate or predictable prospect of useful machine translation." ALPAC (1966) Language and machines: computers in translation and linguistics. A report by the Automatic Language Processing Advisory Committee. National Academy of Sciences, Washington DC.

164 http://world.altavista.com/ A (potentially apocryphal, but nonetheless plausible) example is "the spirit is willing but the flesh is weak" being translated as "the whisky is strong, but the meat is rotten." See http://ourworld.compuserve.com/homepages/WJHutchins/Myths.pdf

165 http://www.bell-labs.com/org/1133/Heritage/Spectro/

166 Each branch of Natural Language Processing has its own principles and approaches, which differ greatly between disciplines. We present introductions to the most relevant topics here…

167 http://www.aclweb.org/archive/what.html

The international scientific and professional society of natural language and computation, the **Association for Computational Linguistics**,[168] has created a wide range of special interest groups including: *SIGDAT* – Linguistic data and corpus-based approaches to NLP; *SIGDIAL* – Discourse and Dialogue Processing; *SIGGEN* – Natural Language Generation; *SIGHAN* – Chinese Language Processing; *SIGLEX* – Lexical Issues; SIGMEDIA – Multimedia Language Processing; SIGMOL – Mathematics of Language; SIGNLL – Natural Language Learning; SIGPARSE – Natural Language Parsing; SIGPHON – Computational Phonology; and SIGSEM – Computational Semantics.[169] Even this short list highlights the variety of approaches to natural language presentation and processing with focuses as diverse as specific linguistic levels (computational semantics), specialised methodologies (linguistic data and corpus-based approaches to NLP) and specific languages.

Speech Technology

When most readers think of 'speech technology,' it is likely they will think of talking computers from science fiction films such as the Voyager computer from *Star Trek* or HAL from Stanley Kubrick's *2001: A Space Odyssey*, both of which 'speak' freely and understand what people say. Modern speech technologies have not quite reached such ease of integrated human-computer communication but they currently address five basic tasks: *Automatic Speech Recognition* (ASR, also called *speech-to-text*); *Voice/Speaker Recognition; Text-to-Speech* (TTS, also called *speech synthesis*); *Natural Language Understanding* (NLU); and the *Voice-enabled Web*.

Automatic Speech Recognition involves the capture and subsequent digitisation of sound waves. The digitised sequence is then analysed in order to discover the phonemes used to build words. The prime benefit of this technology is in data input, and consequently one of its main problems is with the accuracy of the output.

Voice Recognition is concerned with the identification of a person based on voice characteristics. This technology is important for all activities where security and access to specific information are required.

Text-to-speech technology is used to convert written text to a spoken utterance. This technology is based on the fragmentation of text into phonemes and, ideally, takes into account punctuation, phonetic laws and special characters such as numerical digits and currency symbols.

Natural Language Understanding deals with the analysis of spoken words in order to extract data and thereby build a model of the information contained in the utterance. This can involve grammar-based or statistical-based mechanisms or, in some cases, a combination of approaches.

168 http://www.aclweb.org/
169 http://www.cs.jhu.edu/~yarowsky/sigdat.html;
http://www.sigdial.org/;
http://www.dynamicmultimedia.com.au/siggen/;
http://www.sighan.org/;
http://www.clres.com/siglex.html;
http://www.sigmedia.org/;
http://www.cis.upenn.edu/~ircs/mol/mol.html;
http://cnts.uia.ac.be/signll/;
http://parlevink.cs.utwente.nl/sigparse/;
http://www.cogsci.ed.ac.uk/sigphon/;
http://let.kub.nl/research/TI/sigsem/

The Voice-enabled Web brings together telephone and Web technologies, allowing telephones to be used as a means of providing callers with access to Internet based information repositories.

Machine Translation

Machine translation is another important track of work. Its aim is to offer the translation of a text in a source language into another language called a target language. "Machine translation" is a term often used as a synonym of computer-assisted translation (CAT).[170] Machine translation usually involves collecting the information resources (in this case linguistic models, bilingual/multilingual dictionaries and algorithms) necessary for translation and bundling these into a software package which performs translation from source to target language without human intervention. Such programs analyse the structure of a statement or sentence in the source language, split it into translatable elements (depending on the type of language) and finally generate a statement of comparable structure in the target language.

Different software approaches may be based on use of large bilingual or multilingual dictionaries or aligned corpora of previously translated texts. Computer translation tools are not yet capable of generating immediately usable translated texts: the quality of translation is not high enough. So, at the moment, CAT generally involves the use of different tools to assist the translator. The most important of these are *terminology databases and translation memories*.

The translation process involves three basic stages: (i) *Analysing* the words of the source language and converting them into base forms depending on their syntactic roles; (ii) *Transformation* of the base forms into equivalent sequences in the target language, i.e. generation of a rough text (preliminary translation); and (iii) *Revision* (post-editing), covering everything from minor changes to radical text adjustments.

There are three main approaches to machine translation. The *direct* approach involves a minimum of linguistic theory. It is based on detailed bilingual dictionaries, providing corresponding forms in the target language for each word in the source language. The direct approach also takes rules on word order (syntax) into account. The *transfer* approach is based on the use of bodies of texts and examples rather than the strict application of grammatical rules. The *pivot language* approach uses a representation of the text which is independent of any particular language and distinct from both source and target languages. In theory, this method reduces the machine translation process to only two stages: analysis and generation. Research here is related to artificial intelligence and more specifically to methods for knowledge representation.

The most important computer tools in CAT are Electronic Dictionaries, Glossaries and Terminology Databases, Concordances, Online Bilingual Texts and Translation Memories. The last of these are databases where translations are stored for future reuse either in the same text or other texts. Knowledge is thereby accumulated and stored for use in further work, automating the use of terminology and access to dictionaries.

FASP (Fast Translator supporting B2B-ASP Applications) is a European project incorporating an automatic translation tool within an Application Service Provider environ-

170 CRACIUNESCU O., C. GERDING-SALAS, S. STRINGER-O'KEEFFE (2004) 'Machine Translation and Computer-Assisted Translation: a New Way of Translating?' in *Translators & Computers*, Volume 8, No. 3, July 2004, http://accurapid.com/journal/29computers.htm

ment thus easing transactions between businesses in different parts of the world without placing too great a burden on the computing resources of each.[171]

Corpus Linguistics

The use of digital corpora began in the 1960s and corpus linguistics remains a rapidly developing field. The million-word Brown Corpus was made available in 1964, and in the late 1970s and late 1980s Jan Svartvik of **Lund University** compiled the 500,000 word London-Lund Corpus.[172] The compilation of the *American Heritage Dictionary of English Language* was also assisted by the use of a corpus.[173] Corpus linguistics has always been related to mark-up, which is used to aid the discovery of specific elements.[174]

Corpus linguistics dictates that language can be studied effectively and efficiently using samples of 'real world' text. Corpora come in different types: written or spoken; diachronic (covering text from different historical periods in the same language); parallel (translated and aligned texts in two or more languages); and specific corpora (covering texts from one genre, author or topic). Corpora are not static resources but are processed to obtain word frequency lists, concordances and collocations – lists of words which often appear near to each other which are useful in text retrieval. Corpora are important for the study of language development.

Where Language Processing is Currently Used, and How

Natural language technologies can be applied everywhere text or speech is used. As a simple example, the spell-check and thesaurus functions of a word processor are founded on linguistic manipulation. Speech applications include voice recognition systems, text-to-speech programs and automated voice response systems. Web search engines are based on textual mark-up and may also incorporate some text analysis features. Other major applications are listed below.[175]

Information Retrieval

Information Retrieval (IR) deals with the search for specific information. Its applications range from answering natural questions (e.g. "What time does my train arrive?") to finding a particular document or a particular section within a document. The information sought may be multimodal (text, images, audio, video) and/or structured data (databases, metadata). Web search engines are probably the most popular current information retrieval applications. Among the main challenges in this field is that of searching collections of documents in multiple languages, such as the Web and other, smaller and more focused corpora.

There are several important criteria related to IR: *relevance, recall, precision and fallout*.

171 http://www.hltcentral.org/projects/detail.php?acronym=fasp
172 Francis W., H. Kucera, Brown Corpus Manual (Manual Of Information to accompany *A Standard Corpus of Present-Day Edited American English, for use with Digital Computers*), Brown University 1964, Revised 1971, Revised and Amplified 1979. http://www.uni-giessen.de/~ga1007/ComputerLab/corpora.htm#LLC
173 http://www.bartleby.com/61/
174 For more on resource discovery see the section on Information Retrieval, below.
175 HLTCentral maintains an excellent collection of sectoral studies, together with background papers, at http://www.hltcentral.org/htmlengine.shtml?id=155

Relevance deals with the pertinence of the retrieved documents or information to the expressed request. Recall is the percentage of the total relevant documents retrieved by the search compared to the number of all relevant documents in the search collections.[176] Precision is the percentage of relevant documents compared to the number of all retrieved results. Most Web users will be familiar with thousands of pages being returned for a search, many of which may repeat the same information or be irrelevant to the query. Fallout is the complement to precision, the irrelevant documents returned in a search result set.[177]

The Semantic Web

According to the **W3C** definition, the Semantic Web "is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation."[178] For the Web to become a truly machine-readable resource, the information it contains must be structured in a logical, comprehensible and transparent fashion. Current work can be divided into the development of tools for automatic, multilingual knowledge mark-up and formulating ontologies for presenting concepts from different cultures.[179] An ontology is a "formal [i.e. machine-readable], explicit specification of a shared conceptualisation."[180] Ontologies increase search precision thanks to the use of concepts. Concepts are built into hierarchies with defined relationships and logical rules which set priorities and constraints within the relations. The *mapping level* shows the connections between lexicon, concepts and relations. Ontologies can be domain-oriented, task-oriented, application-oriented or general purpose, and are defined using mark-up languages. W3C supports the development of the *Web Ontology Language*, usually abbreviated as OWL.[181]

The proliferation of unstructured material extant on the contemporary Web leads many to doubt the implementability of the Semantic Web vision. In economic and practical terms, the conversion and management of existing material and resources is thought to be too vast an undertaking. Nevertheless, work in the field continues, bringing NLP gradually closer to the field of knowledge representation.[182]

Machine translation

Translation is a major issue for multinational companies and public bodies that need to pass documentation between different sites and departments. To ease this task, many automatic translation systems concentrate on specific subject domains with restricted/controlled vocabularies. The **Instant Web Site Translator** offers Web page

176 Recall is difficult to measure on the Web, since it is by necessity a variable figure.
177 N.B. Information Retrieval is a massive subject area in its own right, and as such is covered in a dedicated chapter, below.
178 Berners-Lee T., J. Hendler, O. Lassila (2001) The Semantic Web: A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities, In: *Scientific American*, May 17, 2001.
179 BUITELAAR P., T. DECLERCK T., N. CALZOLARI, A. LENCI (2003) Towards A Language Infrastructure for the Semantic Web, In: Proceedings of the ISWC2003 workshop on Human Language Technology for the Semantic Web and Web Services, Sanibel Island, Florida, USA, October 20th, 2003, http://www.dfki.de/~paulb/iswc03-hltsw.pdf
180 http://www.virtual-museum.at/glossary/ontology
181 OWL Web Ontology Language, Overview, W3C Recommendation 10 February 2004, http://www.w3.org/TR/owl-features/
182 For much more on the Semantic Web see *DigiCULT Thematic Issue 3: Towards a Semantic Web for Heritage Resources*, available online at http://www.digicult.info/pages/Themiss.php

translation in thirteen languages (English, French, Spanish, German, Italian, Portuguese, Dutch, Greek, Traditional Chinese, Simplified Chinese, Japanese, Korean and Russian).[183] The development of a system for query translation in a legislative document retrieval system is presented in Bounsaythip *et al.*, 'Automatic Translation in Cross-Lingual Access to Legislative Databases,' available online from ERCIM.[184]

For a fun, practical demonstration of automated machine translation, try out the *Dialectizer*.[185] This limited Web resource creates parodies of actual Web pages and text in dialects ranging from Cockney to Redneck, for example:

> Stately, plump Buck Mulligan came from the stairhead, bearing a bowl of lather on which a mirror and a razor lay crossed. A yellow dressinggown, ungirdled, was sustained gently behind him by the mild morning air.
>
> Stately, plump Buck Mulligan came fum de stairhaid, bearin' some bowl uh lada' on which some mirro' and some razo' lay crossed. A yellow dressin'gown, ungirdled, wuz sustained gently behind him by de mild mo'nin' air.
>
> – from James Joyce, *Ulysses*, p. 1: standard and Jive versions.

While light-hearted, the *Dialectizer* highlights the manipulability of textual language and the stages through which it can pass in search of understanding.

In more serious usage, Web services such as *Babel Fish* and **Freetranslation.com** provide tools for automatic translation between real languages together with facilities for sending SMS messages in languages other than your own.[186]

Summarisation and question answering

Computer-assisted summarisation produces shorter versions of texts, condensing the information while maintaining the crux of their structure and content. The primary benefits of summarised documents are the reduced time needed to get the gist of a document and the quicker contextualisation of large amounts of material. There are two basic approaches: producing a completely new text or building a new document on the basis of the source text by copying and modifying parts of it. Summarisation is used in applications where questions need to be answered not on the basis of predefined set of standard answers but rather on the basis of extracting information from documents or databases.

Summarisation comes into its own where the delivery of concise content is important. Applications include report generation, minutes from meetings, the processing of medical records, and Internet search engine results. Summarisation can also be used to provide

183 http://www.worldlingo.com/products_services/website_translation.html

184 BOUNSAYTHIP C, A. LEHTOLA, J. TENNI, Automatic Translation in Cross-Lingual Access to Legislative Databases, Eighth DELOS Workshop User Interface in Digital Libraries, Stockholm, Sweden, 21-23 October 1998, ISBN 2-912335-07-8, http://www.ercim.org/publication/ws-proceedings/DELOS8/tenni.html For a comprehensive list of products see the *Compendium of Translation Software*, a directory of commercial machine translation systems and computer-aided translation support tools edited by John Hutchins, http://www.eamt.org/compendium.html. Another list of machine translation products is available at http://www.foreignword.com/Technology/mt/mt.htm

185 http://www.rinkworks.com/dialect/

186 http://www.freetranslation.com/sms/

versions of documents from different points of view using weighted vocabularies.[187] This technology will also benefit devices with smaller displays, such as palm PCs and mobile phones.

Copernic's *Summarizer* software offers the functionality to summarise Web pages in real time as the user browses through them while simultaneously filtering out adverts and navigation items.[188] The manufacturers claim that this speeds up the time needed to decide whether a Web page is useful or not.

Human interfaces

Human-Computer Interaction (HCI) deals with improving the ease of use of interfaces and systems. It covers equipment for data input and output as well as the ways in which communications are organised. System designers have not always paid as much attention to this important field as they do now, with the trend to offer more intuitive forms of interaction bringing communication closer to natural human languages. A recent development has been the introduction of spoken communication, providing benefits such as improved ease of use, improved speed characteristics and an easier-to-learn interface.[189]

There was a time when all human-computer interaction was based on written command languages which were user-unfriendly and required a fair amount of training to use. Nowadays, the current tendency is to make human computer interaction more intuitive and closer to natural language in both its spoken and written forms. The *ARISE* project (Automatic Railway Information Systems for Europe) offers technological solutions which enable the automatic handling of a large volume of calls on travel schedules.[190] Its technology combines speech recognition with techniques for dialogue modelling and question answering. SIGdial is the **Special Interest Group on Discourse and Dialogue of the Association for Computational Linguistics (ACL)**.[191]

Education and e-Learning

e-Learning is a new concept dealing with educational materials and systems in the electronic environment, adapting the cognitive processes in the learner and the overall organisation of the learning process. It insists on new methods for the preparation of study materials. e-Learning techniques tend to be based on a number of approaches including computer-aided instruction, Web-based learning, virtual schools and universities and computer-supported cooperative work. The advantages of e-Learning are most clearly seen in life-long learning, self-directed study, the growing number of learning objects and study materials and the potential for distance learning.[192]

In e-Learning, the teacher/tutor need not be physically (or even virtually) present. In many cases his or her main function is to *prepare* materials for study. In this sense, NLP technologies could help with issues of multilingualism in learning materials, and adapting materials to the characteristics of a specific user according to a stored profile.

187 See the scenario on the Summarisation of Digitised Newspaper Articles, below, for more on this.
188 http://www.copernic.com/en/products/summarizer/
189 The most prominent HCI technologies are described below.
190 ftp://ftp.dcs.shef.ac.uk/home/njw/Papers/DQA/Discussion/ARISE/AriseFinal.doc
191 http://www.sigdial.org/
192 For more on e-Learning, see *DigiCULT Thematic Issue 4: Learning Objects from Cultural and Scientific Heritage Resources*, available online at http://www.digicult.info/pages/Themiss.php

Brandon Hall's estimate of growth in this sector is that the e-Learning market is likely to grow from US$10.3 billion (€8.44 billion) in 2002 to $83.1 billion (€68.1 billion) in 2006, eventually exceeding $212 billion (€173.7 billion) by 2011.[193]

Text corpora

The World Wide Web could be considered as a gigantic multilingual (and predominantly textual) corpus. As the Web grows, methods of organising and using text corpora assume ever greater importance. In the years before the Web, corpora were primarily of interest to linguists, providing data for dictionary entries, and for language instruction. Their role started to grow as a basis for example-led approaches to language study and machine translation.

Building usable text corpora is not easy. The resources collected in a corpus are usually numerous and corpora sizes are usually measured in millions of words. Besides the issue of digitising the texts themselves, it is also necessary to annotate the collection in such a way that it is usable for a variety of purposes.

The most popular encoding practices include the *Text Encoding Initiative* (TEI), founded in 1987 and the *Corpus Encoding Standard* (CES).[194] TEI offers document type definitions (DTDs) for a variety of textual genres and types. CES is TEI-compliant, and prescribes minimal and subsequent corpus encoding levels.[195] This standardises the encoding practice, and provides a basis for expectations of the quality of the corpus. According to the CES Web site:

> Level 1 is the minimum encoding level required for CES conformance, including markup for gross document structure (major text divisions), down to the level of the paragraph. Level 2 requires that paragraph level elements are correctly marked, and (where possible) the function of rendition information at the sub-paragraph level is determined and elements marked accordingly. Level 3 is the most restrictive and refined level of markup for primary data. It places additional constraints on the encoding of s-units and quoted dialogue, and demands more sub-paragraph level tagging.[196]

It is worth noting that corpora can also be annotated at a *morphological* level; the choice of depth of mark-up will always depend on the project's overall aims.

Processing of ancient texts

Cultural and scientific heritage organisations often deal with very old historical texts. Work on these texts tends to meet certain difficulties: the specifics of the writing system used, the level of standardisation attained, and the linguistic variety of the texts. Texts are often written in unusual writing systems which may not be supported in terms of encoding and the availability of fonts. Despite the development of encoding standards

193 Greenspan R. (2003) Reading, Writing, Pointing-And-Clicking, http://www.clickz.com/stats/markets/education/article.php/2237481
194 http://www.tei-c.org/, For a cultural heritage application example of TEI, see: *DigiCULT Digital Collections and the Management of Knowledge: Renaissance Emblem Literature as a Case Study for the Digitization of Rare Texts and Images* (February 2004), "Indexing Emblem Books on the Internet – the Opportunities offered by TEI", pp.71-77. Available online at http://www.digicult.info/pages/special.php.
195 http://www.cs.vassar.edu/CES/CES1.html
196 http://www.cs.vassar.edu/CES/CES1-4.html

such as *Unicode*, there still remain problems with some historical scripts and their enduring popularity within the research community.[197] A European example is the Old Cyrillic alphabet used in the historical documents of a number of Slavonic countries. Despite numerous discussions, these communities have been unable to reach an agreement on Old Cyrillic text encoding and interchange.[198]

Finally, historical texts from some written traditions tend not to follow strict rules, instead offering much variety on orthographic, lexical and semantic levels. This can place specific conditions on the processing of such collections. In some cases, texts may be stored in normalised form while in others the normalised forms are achieved by means of mark-up elements.[199]

How Natural Language Processing Works

Introduction

There are two core problems for which NLP technologies seek solutions, namely: "How do humans use their natural languages in communications with computers?" and "How can computer tools assist humans in tasks involving the search for natural language documents stored digitally?" Each of these questions is concerned with understanding the meaning of a natural language text or with adding information to a text which can be easily processed in order to locate and extract the document according to some criteria.

Natural languages in communications with computers

This work looks at ways of extracting and codifying meaning according to human intentions, and based on analysis at seven distinct linguistic levels: *Phonetics and Phonology, Orthography and Punctuation, Morphology, Syntax, Semantics, Pragmatics* and *Discourse*. Not all technologies and tools deal with all seven levels, but it is important to understand the capabilities of a specific tool. The following paragraphs deal with each linguistic level in isolation:

Phonetics and Phonology

Phonetics is the science of sounds (phones), while *phonology* is the (language-specific) study of the ways in which sounds function. Phonology deals with three basic components: "an inventory of phonological entities, a set of rules or constraints for describing the relations of these entities, and a framework for describing how the rules or constraints interact with each other to determine accurate formation of particular words or phrases."[200]

197 Unicode is a "character coding system designed to support the worldwide interchange, processing, and display of the written texts of the diverse languages and technical disciplines of the modern world. In addition, it supports classical and historical texts of many written languages." http://www.unicode.org/

198 Problems may also arise with texts written in character sets featuring pictographs and other symbolic characters.

199 Compare this with the uses of *lemmatisation* in Information Retrieval, for example.

200 Janet B. Pierrehumbert (2000) *The Phonetic Grounding of Phonology*, Northwestern University, Evanston, IL, USA.

Phonology is crucial for speech technologies. In automatic speech recognition, individual phonemes are distinguished and mapped to letters or groups of letters while, with text-to-speech technologies, phonological knowledge helps produce lifelike, convincing pronunciation and intonation.

Orthography and Punctuation

Orthography is a linguistic discipline which prescribes a set of rules for writing correctly in a specific language.[201] The orthography of the English language, for example, is relatively complicated, causing difficulties in automatic speech recognition. Even when sounds themselves have been recognised, finding the respective word representation is not always straightforward.

Punctuation deals with the correct use of punctuation marks, in themselves a form of symbolic, structural mark-up. Knowledge of punctuation is important for text-to-speech systems in order to achieve realistic intonation. Systems generating written text also utilise punctuation rules to make their output easier to read.

Morphology

Morphology studies the structure of words, and included mechanisms for deriving new words or word forms. The smallest units in this linguistic discipline are the *morphemes*.[202] Languages are classified into several groups depending on the ways in which their words accord to grammatical function. In *isolating* languages, the grammatical function of a word depends on the word order. In *agglutinative* languages, new word-forms come about by 'gluing' constituent parts of existing words together, with each part expressing a single definite meaning (e.g. one for a specific case, another for singular/plural person, a third for the gender, etc.) In *inflective* languages, word-forms change according to grammatical function, with one word-ending representing several grammatical characteristics at the same time.

Morphology has three basic mechanisms: inflection, derivation, and compounding. Inflection denotes a change in a word-form's grammatical function, usually by adding a suffix and/or ending.[203] Derivation denotes the cases when a word with new meaning is received from another words by adding an *affix*. Affixes are morphemes added to a base (root) morpheme in order to create a new word form. Affixes can either precede the root (*prefix*) or follow it (*suffix*). Compounding denotes cases when a word with a new meaning comes about as a combination of two or more existing words.

Morphological analysis is essential in many NLP applications for classifying the word-forms that appear in a text. This is the first step towards grammatical parsing, and the attempt to extract a text's *meaning*. In text retrieval, morphological analysis is important for finding matches to a query appearing in a form different from the query formulation (known as 'fuzzy searching').

We should note that the morphological models used in NLP differ according to the

201 From Greek *ορθος* (correct) and *γραφειν* ("to write")
202 In his seminal work *Language* (1933), the American linguist Leonard Bloomfield (1887–1949) defined morphemes as the "smallest meaningful unit in a given language."
203 http://www.cogsci.princeton.edu/cgi-bin/webwn

language type. NLP's early development was fundamentally influenced by models created for the English language, which is less complicated on this level than highly inflected languages such as Russian, Czech, German, and French.

Syntax

Syntax is the study of a text's *word order*, with particular attention to sentences and individual clauses. The process of text analysis which attributes grammatical functions to individual words is known as *parsing*. This is done by splitting character strings into distinct units (or 'tokens') and then modelling the sentence structure as a hierarchical *parse tree*. Parsing software tends to be language-dependent.

In machine translation, hierarchical structures are used to map the representation of the text in the source language to the target language representation. In text retrieval, formal representation of syntactic structures allows us to look not only for keywords but also for the answers to textual questions.

If a sentence is grammatically correct but features instances of unknown words, it may still be possible to draw some meaning in it. A famous example is Lewis Carroll's poem *Jabberwocky*, which begins:

Twas brillig, and the slithy toves
Did gyre and gimble in the wabe.
All mimsy were the borogoves,
And the mame raths outgrabe.[204]

Carroll's verse appeals primarily to the senses, with onomatopoeic coinages of nouns and verbs side by side with standard conjunctions and determiners.[205] Other sentences may be linguistically correct but without ascribable meaning, such as Chomsky's famous example, "Colorless green ideas sleep furiously."

Semantics

Semantics is the study of meaning.[206] Natural languages differ from computer languages in that a single word is able (indeed likely) to have several meanings. The specific meaning of an instance of a word is derived from its context. These matters are covered by lexical semantics, which also deals with the study of relations between words, such as *antonymy, homonymy, synonymy*, and *polysemy*.

This type of knowledge is important in NLP for applications involving the *understanding* of natural language. It is also essential for text searching and retrieval since information on specific topics could be covered in documents where, for example, antonyms of the search term are used. Semantics is also crucial in branches of computer science such as knowledge representation. The *Semantic Web* concept also heavily depends on semantic meaning of documents on the Web.[207]

204 Lewis Carroll (1932–1898), *Through the Looking-Glass*.
205 Professor Lev Shterba has suggested a Russian equivalent: Глокая куздра штеко будланула бокра и кудрячит бокрёнка.
206 The word comes from the Old Greek σημα – sign. Σημαντικος – important meaning.
207 For more on the Semantic Web, see *DigiCULT Thematic Issue 3: Towards a Semantic Web for Heritage Resources*, available online at http://www.digicult.info/pages/Themiss.php

Pragmatics

The pragmatic level deals with knowledge which is not directly expressed in the document text but which may be essential for deriving its meaning. This knowledge may be known or unknown to the user. In many cases this has to do with classification: for example, a search for 'birds in Europe' should return results describing birds in Poland, Iceland and Portugal, since all of these countries are in Europe. This field will be hugely important for text retrieval applications when it develops further.

Discourse

Discourse is the study of the different types of text structure. Discursive knowledge is crucial since texts such as encyclopaedia entries, technical documentation and business letters tend to have clearly defined structures, allowing the order of elements appearing within them to be formalised. This sort of knowledge is useful in the generation of texts of a specific type and for retrieval of documents from the same group – yet another area in which XML is of key importance.

Endnote

As we can see, there are a variety of models for presenting knowledge at different levels and granularities and many different algorithms or approaches to processing linguistic data. There are essentially two types of tasks being solved: *analysis* (of grammatical structure; of meaning – applied in text retrieval and machine translation) or *synthesis* (as applied in natural language generation – written and spoken). These approaches can also be distinguished according to the use of textual analysis, or mark-up. In the latter case, meaning is not extracted from analysis of the text but rather depends on the depth of the mark-up work. Another classification criterion is the distinction between written and spoken text. Most applications are directed towards one of these types, but there are mixed solutions where a text is initially generated in written form before text-to-speech technologies are applied to read it aloud.

The methods applied vary according to the specific aims of each NLP venture. Some come from linguistics and deal with the suggestion and use of formal language models of language applied over different linguistic levels. Other methods come from the field of statistics and are mainly applied to corpora materials. General computer science methods have also been applied in this field in order to offer better techniques and methods for search. Considering the huge amount of data which have to be processed, it is important for optimised methods for fast access and reference to be put in place.

Automatic voice and speech recognition

Definition

Automatic voice recognition (also known as *speaker verification*) is a form of biometric identification which involves the automated identification of a specific individual's voice by checking his or her "voiceprint" against a previously recorded voiceprint database. It involves a simpler process than speech recognition since there is no need to identify the content of the sound sequence, only the aural and vocal characteristics of the voice. During the process, the sound signal is digitised and then compared to previously recorded samples stored in a database. The result is simply a "yes" or "no" statement depending on whether the speaker is matched with the recorded voice.

Voice recognition is often used in call centres to replace such procedures as entering a PIN or password via the touchtone keys on the telephone. It can also be used alongside automatic mark-up tools to recognise a particular speaker's voice in conversation processing.[208]

Automatic speech recognition is the branch of computer science dealing with systems that can recognise spoken text. The same term can be used more specifically to refer to the process of analysing digital audio signals to determine sounds and words uttered by a speaker. The terms *speech recognition and voice recognition* are often used interchangeably, however it is more correct to associate voice recognition with the identification of a particular speaker and speech recognition with the identification of words independent of their speaker. Of course, some tasks require both functions to be performed.

How does it work?

There are four main steps in the recognition process: *input signal capturing, preliminary processing, recognising* and *communicating*. For the first phase, the sound waves (usually generated by a microphone) are in a form that the computer cannot understand so the sound card must convert the analogue waveforms into digital audio sequences ('sound digitisation.')

At the preliminary processing stage, important features are extracted from the digital signal. It is parsed into segments which are then compared against a language-specific database of known phonemes. At the word level, phonetic sequences are compared with a known vocabulary or dictionary of words. Part of the database will consist of preliminary recorded sound patterns while the remainder is built with the assistance of the user who 'teaches' the software by repeating keywords.[209] The most common methodological approach used is the *Hidden Markov Model*.[210] This statistical method recognises speech by calculating the probabilities of phonemes appearing after a specific sound sequence of chosen length; a search procedure called a *Viterbi search* is used to determine the string of phonemes with the highest probability.[211] Different types of searches are used in the algorithm to increase its speed. One possibility is the use of *lattices*, arrays that record the beginning of each word and multiple endings reducing search times significantly.

In the final phase, the recognised words are passed to an external application, such as a word processor or database or (in the case of voice command recognition) to the command interpreter of the computer. According to a Forrester Research report, the current *accuracy rate* of speech recognition software is estimated at around 90%, approximately one error per sentence.[212]

208 In the future, further mark-up could potentially be added to indicate features such as emotion, sarcasm, or anger, although this would be very advanced.

209 Some contemporary systems recognise specific dialects.

210 This model is also used for other recognition tasks, such as optical character recognition.

211 These methods are described in more detail in Frederik Jelinek (1998) *Statistical Methods for Speech Recognition*, Bradford Books

212 http://www.forbes.com/2000/07/28/feat_print.html

Types of Speech Recognition

Speech recognition systems can be classified according to four main criteria: *the way that words or phrases are spoken; single versus multiple speakers; particulars of hardware set-up*; and the potential for *interactive voice response* (IVR).

There are two types of system defined by the way words or phrases are spoken: *discrete* systems and *continuous* systems. In a discrete speech recognition system – typical of older applications in the field – words are pronounced separately. In current systems, this approach is used mostly as an add-on to IVR systems (see below). In continuous speech recognition systems, words are spoken in a natural, conversational manner. This way of speaking is more natural for the user than the discrete type. Continuous systems are faster than discrete systems, and are rapidly becoming dominant.

The single versus multiple speaker criterion categorises systems according to their ability to distinguish between a single, previously identified speaker (speaker-dependent) and many speakers (speaker-independent). Most desktop-level systems must be calibrated for the user's voice, for example, the automatic subtitling applications used on live television broadcasts and voice dialling for mobile telephones.[213] Speaker-independent systems tend to have smaller vocabularies than speaker-dependent systems. This trade-off is made to ensure effective operation with a larger and broader user community. Speaker-independent systems are often found in menu-based applications, where user utterances can be predicted, or even limited to a certain set. One of the advantages of using speech recognition for these applications, in preference to IVR, is that they are hands-free for the user, increasing convenience and reducing data entry times.

Speech recognition software can be installed on the client or the server side. Speaker-dependent systems are installed mainly on single-user PCs, while multi-user speaker-independent systems are more often found on server-based systems. Most PC-based systems are single-user, speaker-dependent and employ continuous-recognition techniques. These incorporate dictation-type systems or hands-free user interfaces, enabling some people to perform tasks they could not otherwise carry out. Speaker-independent, continuous-recognition systems demand greater processing power and data storage requirements than speaker-dependent systems, hence these systems are predominantly sited on server-based systems.

Interactive voice response (IVR) systems are applications where a user's commands are recognised via a telephone line. Typical applications are in banks for accounts enquiry, airline ticket reservations, customer services and call centres. Interactive voice-response systems have restricted speech recognition capabilities since many of the system's functions are fulfilled pressing specific buttons on a telephone keypad. IVR systems provide output voice data either by using pre-recorded utterances that can be played back on demand or through *text-to-speech* technology (TTS). The primary advantage of TTS over pre-recorded speech is its capability to generate speech from any textual sequence.

213 The *Transcriber* tool assists the manual annotation of speech signals, particularly news broadcasts, helping users cut long duration speech recordings into segments, transcribe them, and label 'speech turns, topic changes and acoustic conditions.' http://www.etca.fr/CTA/gip/Projets/Transcriber/

Benefits of Speech Recognition

Speech recognition offers several important benefits such as: providing easier ways for data entry; improving computer access for people with disabilities; protection against repetitive stress injury (RSI); freeing the user's hands and eyes for other tasks; and potential cost savings.

Where is Speech Recognition used?

Speech recognition systems have become more commercially viable in recent years, assisted by advances in computational power and increases in computer memory capacities. Because of their technical limitations and high cost, ASR systems had previously only been found in very specialised applications. Callers can now use voice commands to perform numerous operations in areas including social services, stock trading, banking, insurance, travel and airline booking, goods tracking, restaurant and hotel reservation, and repeat medical prescriptions. The **UbiSoft** video game *Rainbow Six 3* was one of the first to employ **Fonix** speech recognition features and players enjoy the facility for issuing computer-controlled characters with commands.[214]

Another option is to offer voice portals which can read Web content to users and follow their verbal commands. ASR is likely to be used in the near future for e-learning applications, online gambling, domestic applications (e.g. voice commands for ovens, heating systems, etc) and in wearable computing.

Text-to-speech and speech synthesis

Definitions

Speech synthesis and *computer-generated speech* technologies work in the opposite direction to the speech recognition process. Rather than taking sounds and analysing them, TTS systems take text strings and pronounce them aloud. *Speech prosthesis* involves the application of computer science in the linguistic assistance of people with disabilities. It focuses on computer-generated speech for people who are unable to speak intelligibly. *Multimodal speech synthesis* uses visual aids, such as talking avatars, to complement synthesised speech with non-verbal information such as nodding, winking, and smiling.[215] Since a large percentage of human communication is non-verbal, this complementary visual information helps facilitate the understanding and comprehension of synthesised speech.

How does it work?

Text-to-speech systems use three different technologies: *formant synthesis, diphone concatenation* and *unit selection*. Formant synthesis works using language-specific rules that simulate the generation of human speech. The software needed for this imposes only a

214 http://www.ubi.com/; http://www.fonix.com/; http://news.teamxbox.com/xbox/5059/Games-with-Fonix-Speech-Now-Available

215 See *DigiCULT Technology Watch Report 2*, pp. 67-89, for much more on the current and potential uses of avatars in the heritage sector.

very small workload on computer resources. Diphone concatenation consists of defining phonetic speech units (such as allophones, diphones, and triphones) in text strings, and reproducing them by concatenation of pre-recorded sound units contained in a database. Complicated signal processing is performed allowing modification of the duration and pitch of speech units, as well as spectral smoothing of the signal at the concatenation points in order to provide a more lifelike effect. Special attention is paid to preliminary textual analysis to suggest the intonation that should be achieved.

Unit selection employs the generation of synthesised voices using a library of pre-recorded human speech units. This modern technique is characterised by the use of algorithms which search a database for the unit that most closely matches the necessary signal parameters, avoiding intensive signal processing.

Where it is used?

TTS systems are used to translate written information into aural information, especially in mobile applications such as voice-enabled e-mail and unified messaging. Systems can be built on *TTS-engines* which can be integrated into existing applications where synthetic speech serves as the information carrier, or these can be built-in into newly developed products or services. This approach offers a great degree of flexibility to application developers since it provides various means to operate with considerable amounts of dynamic text. As a result, costs can be reduced and developments accelerated by avoiding the need for pre-recorded prompts. The use of such an approach is illustrated by **IBM**'s *Embedded ViaVoice Multiplatform Edition*, which integrates speech technology into mobile devices such as smart phones and personal digital assistants (PDAs), giving users voice access to information from home or work.[216] TTS is also used to assist visually impaired users via systems that automatically read the contents of the screen, and in voice portals on the Web.

Some typical application fields of TTS systems are summarised below:

- *Education and Language Learning*. TTS engines are used in "edutainment" applications in conjunction with speech recognition engines. The software helps users to learn while interacting with animation characters or avatars, controlled by spoken commands. At the same time the pronunciation of the user is compared with that of a native speaker, and corresponding feedback is issued to the user.
- *Voice portals and interactive voice response systems*. Communication providers offer various information services via TTS systems, including event scheduling (movies, theatres, sport events, etc), location-based weather reports, product details, pricing information and product availability. The latest voice portals rely on the combined use of speech recognition, text-to-speech and VoiceXML technologies, allowing callers to navigate Web sites. Dynamic Web content is accessed by spoken commands converted into text and used to query a database in real-time. The query results are then converted into audio and relayed to the user.
- *Telematics*. This includes auto maintenance and information services (news, convenience facilities and traffic reports) provided automatically. The service can be combined with GPS and wireless data communication technologies in order to offer driving directions and other location-based services.[217]

216 http://www-306.ibm.com/software/pervasive/embedded_viavoice_multiplatform/
217 See the section on Location-Based Systems, below.

- *Desktop utilities*. Developments in this area come in the shape of intelligent on-screen agents which communicate with users through voice or typed commands and which perform different tasks such as searching the Web or retrieving specific information. Query results can be displayed onscreen or spoken using TTS engines.
- *Banking and e-Business applications*. TTS applications are often integrated into tele-banking services to provide callers with constantly changing information such as prices, stock quotes and currency exchange rates. TTS is often used in e-Business for voice enabled solutions delivered through Web, middleware or telephony, speeding up the relay of information.
- *Improved access*. Screen readers can assist blind or visually impaired computer users by reading information aloud via TTS engines. Most packages are adaptable, and can be combined with other assisting technologies such as refreshable Braille displays like the Hal Screen Reader.[218]

Natural Language Understanding

Speech recognition involves a computer passing recognised utterances to an application without necessarily *understanding* what is being said. Comprehending the correct meaning of speech is the object *Natural Language Understanding* (NLU). This process combines the efforts of different sciences and technologies such as statistics, linguistics, artificial intelligence and speech recognition. It offers many advantages over conventional human-computer interaction techniques. For example, the elimination of complex and hard-to-remember commands, cumbersome menu options and key-actuated processes provide users with easy and transparent access to information and services, thus increasing their satisfaction and attention to their tasks.

The Voice-enabled Web

The Voice eXtensible Markup Language (VXML)[219] is the basis of the voice-enabled Web and is to speech what HTML is to visual Web displays. The two differ in their means of delivery: where HTML provides visual applications delivered to the user's display in the form of Web pages, VXML provides audio applications delivered over the telephone. The main difference between the traditional Web and the voice-enabled Web is that VXML users access the Web by means of speech recognition and touch-tones for input, and pre-recorded audio and TTS synthesis for output. VXML applications are accessed via a voice capable device that accepts audio and keypad input and delivers audio output. Mobile and standard telephones, together with some modern PDAs, meet these criteria.

Voice portals use telephones as a means for providing access to information repositories in a way similar to Web portals acting as information hubs for Internet users. Voice portals use voice-recognition technology to offer callers continuous access to information such as weather forecasts, stock quotes, business news and traffic reports, without the need for telephone touch pads or a dedicated operator.

218 http://www.dolphinuk.co.uk/index_dca.htm
219 W3C Voice Extensible Markup Language (VoiceXML) Version 2.0, W3C Recommendation, March 16th 2004 http://www.w3.org/TR/2004/REC-voicexml20-20040316/

Natural Language Processing in the Heritage Sector

Introduction

The possibilities for Natural Language Processing in the heritage sector are, presumably, limitless: if language itself is central to human communication, near-term advances in NLP should empower our interaction with computers to a startling extent. Possible applications of this technology in the heritage sector include the *presentation of collections, multimedia guides, improving access, information retrieval* and *multimedia guides*. We consider each of these below…

Presentation of collections

Speech technologies and a museum visit. This could benefit two distinct groups of users: (i) visitors navigating a (real or online) collection who wish to receive audio guidance and background information; and (ii) visually-impaired visitors. Speech technologies are often incorporated in agents serving as virtual tour guides.[220] These can be linked with multimedia guides in order to provide a fuller visiting experience.

Multilingualism: machine translation of collections information. Apart from countries with two or more official languages, most cultural and scientific heritage Web sites are monolingual. In the rare cases where an alternative language is available, it is usually English. This denies access to a sizable proportion of potential users. Given the high volume of information contained within Web sites, human translation of the materials may not be an efficient approach; instead NLP techniques could be used to provide translations into a host of languages. Some intricacies are bound to be lost in translation but the gist of the material should come through.

Summarisation of texts for quick orientation. In time, this will enable curators to store long descriptions of objects and thus to deliver targeted descriptions to users, depending on factors such as age, interests, experience and the type (and size) of device they are using. This also ties in with *profile-driven collection presentation*, a field of work expected to become more popular over the next few years. It is a labour-saving approach which cuts the time and effort involved in producing multiple presentations of collections according to a wide range of possible user profiles. This also links with issues of e-learning and social inclusion.

Text indexing

Text indexing applications analyse texts and assign keywords to them. Their first uses were in large bibliographic systems, but they are now more often associated with tools for the annotation of Web documents. Automatic XML mark-up of files is now possible

220 See *DigiCULT Technology Watch Report 2*, particularly the chapter on Cultural Agents and Avatars (pp. 67-89), for more on virtual tour guides. http://www.digicult.info/pages/techwatch.php

and tools exist for identifying dates and proper names in correspondence (for example), whether these are given in formal or informal style.[221]

Multimedia Guides

Multimedia guides allow the presentation of a subject using different types of data: texts, still images, animation, audio, and video. This can increase the attractiveness of the presentation and allows users to study the information in their preferred style. In previous years, multimedia guides were restricted to CD-ROM distribution, but with the development of Internet technologies, multimedia guides can be easily published on the World Wide Web. For example, the **Art Institute of Chicago**'s *Cleopatra: A Multimedia Guide to Art of the Ancient World*[222] is "an interactive journey through the collection of ancient art" featuring the ancient cultures of Egypt, Greece, and Italy on the basis of the museum's collection. It offers the user the choice between English and Spanish for the interface language.

The NLP issues which have to be taken into account in the various types of multimedia guides generally relate to the interface language and inbuilt capabilities for automatic translation into different languages. A growing trend in multimedia guides involves the use of PDAs: if users bring *their own* computers to an institution, managers no longer need to worry about buying and maintaining expensive and potentially temperamental machines.[223] Furthermore, if the users' mobile computers can automatically inform a central system of the language in which they prefer to receive content, further potential difficulties are alleviated. See O'Donnell, M. (2000) 'Museum Audio Guides which Adapt to the User and Context' for more on the possibilities for NLP and multimedia in the museum environment.[224]

Access for disabled users

Augmentive and alternative communication[225] and *adaptive technology* are two terms dealing with enabling technologies for disabled users. NLP and speech technologies in particular play a major role in helping visually impaired users communicate with computers. Hearing impaired users can communicate with computers via avatars using sign language. Special symbolic input and output for users with motor impairments can be combined with specialised devices such as special keyboards, or eye mice.[226]

221 See for example Akhtar, S., R.G. Reilly and J. Dunnion, 'AutoMarkup: A tool for automatically marking up text documents' http://cortex.cs.may.ie/papers/SA_RR_JD_CICL.pdf

222 http://www.artic.edu/cleo/

223 CHEVERST K., N. DAVIES, K. MITCHELL, A. FRIDAY and C. EFSTRATIOU (2000). Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences Proceedings of CHI 2000. Amsterdam.

224 http://www.wagsoft.com/Papers/Seville2000.pdf

225 McCoy, K. F., Demasco, P. (1995) Some applications of natural language processing to the field of augmentative and alternative communication. In Proceedings of the IJCAI '95 Workshop on Developing AI Applications for Disabled People (pp. 97-112). Montreal, Canada.

226 See *DigiCULT Technology Watch Report 1*, "Human Interfaces" (pp. 117-148) for more on this area.

Multilingual interfaces

Multilingual interfaces contribute to ease of use, reduction of the learning curve in mastering computer applications and improved information access.[227] Language and speech technologies play a key role here. The discussion on building multilingual applications in library automation about 10 years ago was focused on controlled multilingual vocabularies.[228] Current focal points of discussion and practical work include multilingual access via the World Wide Web, translation issues and questions of transliteration and character sets. For example, the *ePatent: Multilingual access to European Patent databases* project funded by the European Commission's eContent programme aims at providing a European wide cross lingual repository of patent information in four languages.[229]

Information Retrieval (and the Semantic Web)

The rapid increase in the amount of material available on the Web can only deepen the problems of locating relevant information and objects. Bearing in mind the scattered collections on specific heritage topics, information retrieval has always been a key concern for our community. Building a comprehensive virtual library of resources, which may be scattered in numerous institutions in various countries, would require an unattainable concentration of effort and would place unmanageable demands on financial and management resources. Current Web technologies offer another solution namely the ability to search expanding and distributed virtual collections of materials, prepared and maintained by different institutions. The development of such virtual distributed collections is not necessarily an organised action but rather a consequence of separate institutions acting in the interests of the same standards and goals. It would be misleading to claim complete coverage of any subject, but if the organisations apply similar standards for encoding, quality and level of detail, the results will serve the needs of researchers and citizens alike. From this point of view, issues of standardisation and quality of information encoding become ever more crucial.

Natural Language Processing embraces and overlaps many areas of computing which are on the surface unconcerned with spoken or written language. The Semantic Web is one such area worth watching in terms of the automation and standardisation of approach. Some organisations are already working on presentation of their collections according to the principles of the Semantic Web, e.g. the excellent *Finnish Museums on the Semantic Web* portal.[230] Institutions wishing to harness Semantic Web capabilities will be obliged to adapt existing ontologies, or to create their own in concord with others.[231]

227 Multisensorial, Multilingual Interfaces and Virtual Environments, Report on the IST Program Consultation Meeting 10, Brussels, 26-27 April 2001, http://www.hltcentral.org/usr_docs/FP6/Interfaces/pcm10report.pdf

228 Report by G. Clavel, Workshop "Multilingual problems in networking" 20th Library Systems Seminar Quality of Electronic Service, http://www.kbr.be/elag/20seminar/workshops/shop13.htm

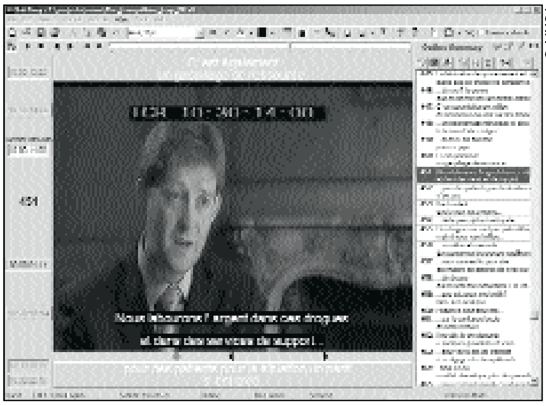
229 http://www.eu-projects.com/epatent/

230 http://museosuomi.cs.helsinki.fi/

231 See Hyvönen E., S. Saarela, K. Viljanen (2004) "Application of Ontology Techniques to View-Based Semantic Search and Browsing" in *Proceedings of the First European Semantic Web Symposium* (ESWS 2004), Springer-Verlag, :http://www.cs.helsinki.fi/group/seco/museums/
There is much shared ground between research into Natural Language Processing and Information Retrieval (IR). For more on this overlap please see the section on Information Retrieval, below. The potential of the Semantic Web is covered in more detail in *DigiCULT Thematic Issue 3: Towards a Semantic Web for Heritage Resources*, available online at http://www.digicult.info/pages/Themiss.php

Case Studies

MUSA – MUltilingual Subtitling of multimediA content[232]


© MUSA

MUSA subtitling in French

Developments in mass media and communication, such as digital TV and DVD, seem set to overcome the physical borders of countries, leading to the creation of a globalised media audience. In such a unified framework of mass communication, subtitling will play a critical role. In many countries, subtitling is the most commonly used method for conveying foreign language content to a native audience. However, the actual task of producing subtitles is an expensive and time-consuming task, and generally carried out manually. An hour-long programme, for example, typically requires between seven and fifteen hours of human effort.

In view of the expansion of digital television and the increasing demand for manipulating audiovisual content, tools producing subtitles in a multilingual setting are set to become indispensable for the subtitling industry. Operating in this setting, *MUSA* aims to develop a system combining speech recognition, advanced text analysis, and machine translation to help generate multilingual subtitles automatically. The system converts audio streams into text transcriptions, condenses and/or re-phrases the content to meet the spatio-temporal constraints of the subtitling process (i.e. the amount of characters that can appear on the screen at any one time), and produces draft translations in at least two language pairs. Three European languages are currently supported: English as source and target for subtitle generation, and French and Greek as subtitle translation target languages.

The MUSA project started on 1st October 2002 with an expected duration of thirty months. The total budget is €2,589,123 of which the European Union's Fifth Framework Programme (FP5/IST) contributed €1,554,451. The project consortium comprises the **Institute for Language and Speech Processing** (Project Coordinator, Greece), **Katholieke Universiteit Leuven** (Belgium), **Systran** (France), **Lumiere Cosmos Communications** (Greece), the **Centre for Dutch Language and Speech**, and the **British Broadcasting Corporation**.[233] These participants cover the whole spectrum of organisations involved in the subtitling industry, from academics to content generators and broadcasters. The user partners (Lumiere and the BBC) have provided all relevant system data, feedback concerning the best practices that are followed by professional human subtitlers and the structuring of the subtitling market. Current practices

232 This case study is based on an email interview with Stelios Piperidis, Head of the Language Technology Applications Department at the **Institute for Language and Speech Processing**, Greece. The interview took place during June 2004. http://sifnos.ilsp.gr/musa/

233 http://www.ilsp.gr/; http://cnts.uia.ac.be/cnts/; http://www.kuleuven.ac.be/; http://www.systran.com; http://www.lumiere.gr/; http://www.bbc.co.uk

and standards followed by the world's major media groups form the basis on which MUSA's subtitling component converts program transcripts to subtitles. Standardisation is performed along several parameters: spatial, temporal and editorial.

The architecture for MUSA's multilingual subtitle production line includes the following functional modules:

1. An *English automatic speech recognition (ASR) sub-system* for the transcription of audio streams into text, including the distinction between speech and non-speech sounds, speaker identification, and adaptation to a given speaker's style;
2. A *subtitling* sub-system, producing English subtitles from English audio transcriptions. This aims to provide maximum comprehension while complying with spatio-temporal constraints and other linguistic parameters;
3. A *multilingual translation* sub-system, integrating machine translation, translation memories and terminological banks, for English-Greek and English-French translations.

MUSA in Greek

The same footage subtitled in English

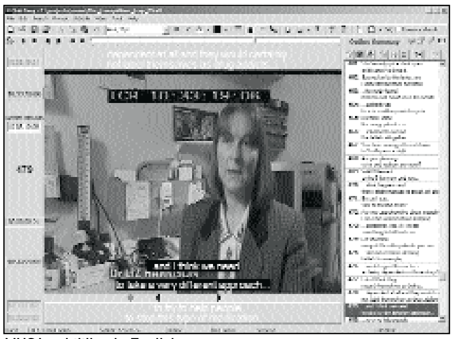
The component modules of the automatic speech recogniser include a pre-processing stage, the acoustic model (AM), the language model (LM), the lexicon and the search engine. The speech recogniser accepts as input a pulse-code-modulated audio file of 16-bit samples at 16 kHz, and its output is a time-tagged text containing a word-by-word transcript of the input audio, with segments of transcript corresponding to sentences. The subtitling sub-system comprises the constraint formulation and calculation module, the text condensation module and the subtitle editing module. The input to the subtitling sub-system is an English transcript with time codes, words, segments, internal punctuation and speaker turns, and the output is the corresponding subtitles in English. The translation sub-system comprises the *TrAID* translation memory module and the *Systran* machine translation engine.[234] Input to the translation sub-system is the English subtitles from the subtitling system, giving an output of Greek or French subtitles complete with time codes. All data exchange between the system components is performed via XML files obeying predefined DTDs. The French and/or Greek subtitles are linguistically processed and converted into the STL subtitle format.[235] The formatted subtitles can then be viewed and edited in a subtitle editor.

The main challenging issues in developing the prototype were the performance of the speech recogniser under difficult noise conditions and the performance of the translation component in unrestricted subject domains. The former was alleviated by making use of

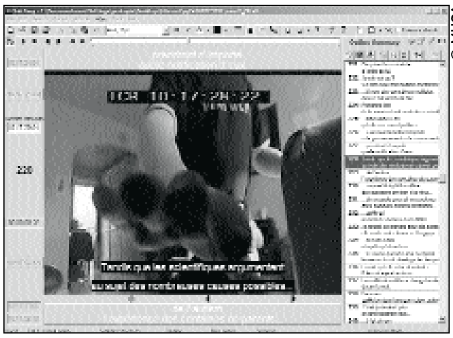
234 http://www.ilsp.gr/traid_eng.html; http://www.systransoft.com/
235 http://www.ebu.ch/

the script (or transcript) of the programme when available, while automatic customisation techniques were adopted for the latter.

An initial evaluation round has been performed at both component and system levels, with evaluation tasks being performed either automatically or by human judges. The MUSA speech recognition component has been evaluated by calculating word error rate and accuracy of the audio-transcript alignment. The subtitling component has been evaluated by human judges who scored the English subtitles produced for grammatic and semantic acceptability, and automatically by comparing the generated subtitles with a set of gold subtitles based on counting by *n-gram* word prediction. The translation component has been evaluated by human judges, rating each translated unit according to a set of scores. Apart from the evaluation of components with high quality input data, the same component has been evaluated with data resulting from the processing performed by the previous components in the processing chain. System evaluation has been performed by professional subtitlers, who were asked to correct the automatically generated and translated subtitles and record the time required to elevate system results to accepted industrial level output. The automatically-generated subtitles and the corrected versions have been automatically compared and the edit distance calculated. Overall results have been encouraging, especially when the speech recognition component is "aware" of the script or transcript of the programme. A further round of evaluations has been scheduled for the northern winter of 2004.



MUSA subtitling in English



MUSA subtitling in French

Experiments with other text compression or simplification techniques are ongoing and the MUSA prototype continues to develop. The interaction and integration of automated solutions with the whole programme production chain is under investigation, and tighter coupling with video processing techniques is among the main goals for the future. MUSA's work sits at the heart of contemporary NLP research, dealing as it does with issues like interfacing content modalities, speech/text/video, and so on, in a commercial and scientific context. Given culture's strong interrelations with language and its various uses and manifestations, the MUSA team believes that its work holds considerable benefits for the cultural community as a whole.

M-PIRO – Multilingual Personalised Information Objects[236]

The M-PIRO project was an IST-funded initiative concerned with developing the

236 This case study is based on an email interview with Dr Colin Matheson and Dr Jon Oberlander of the **University of Edinburgh**'s Language Technology Group, and on materials available on the Web. http://www.ltg.ed.ac.uk/mpiro/

language engineering aspects of Personalised Information Objects (entities capable of responding to requests for information by taking into account what requesters already know, what they are most interested in, and how the related information is to be made available")[237] in virtual and other museum settings, with particular regard to their delivery across different languages. The project ran for three years from February 2000 to February 2003, and involved six partners: project coordinators at the **University of Edinburgh** (Scotland); **Istituto Trentino di Cultura** (Italy); the **National Centre for Scientific Research "Demokritos"**, the **National and Kapodistrian University of Athens**, the **Foundation of the Hellenic World** (Greece); and **System Simulation Ltd** (England).[238] Over 300 person-months were spent on the project, representing an average of eight full-time researchers throughout. The total budget was just over €2M, the EU contribution being €1.25M.

The M-PIRO Web front end

M-PIRO took as its starting point the position that while it was easy to provide information about digital objects by, for example, clicking on the object in a browser, this kind of interaction did not provide information tailored to the user's interests or preferences or take into account the user's prior exchanges. For that to happen, the information needed to be stored in a different, non-textual fashion and transformed on demand into a spoken or written message in the language of the user. This language generation process took into account factors such as context and the user's personal preferences, so that it looked to the user as if the object had been stored all along as a Personalised Information Object. The project's main goal was thus to develop the language engineering aspects of Personalised Information Objects, concentrating on multilingual information delivery, in English, Greek, and Italian, for virtual and other cultural settings.

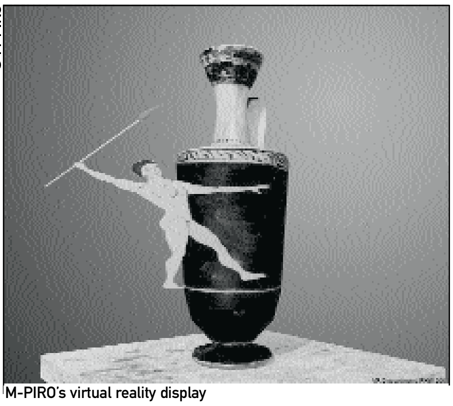
Many museums already provide hand held devices which act as multilingual spoken guides to collections of museum objects.[239] Each description in the source language can be translated into descriptions in the target languages. For audio guides, these can be used in scripts for recordings in each language. However, a further complication arises when the descriptions also have to be personalised for individuals. Potentially many versions of each description have to be written, translated and recorded. This presents a significant problem of scale, exacerbated by the fact that new objects can be added to collections at any time, requiring new multiple descriptions in multiple languages. The M-PIRO approach was to harness symbolic author- and user-modelling techniques in order to address the scaling problem without demanding that knowledge experts became language engineers.

M-PIRO partners specifically set out to take technology originally developed for English and transfer it to other European languages, while at the same time improving user modelling and author support. The mix of project partners was specified at the outset to include the appropriate complementary expertise, with speech and language tech-

237 http://www.aueb.gr/users/ion/docs/verona_mpiro_paper.pdf
238 http://www.ed.ac.uk; http://www.itc.it/; http://www.demokritos.gr/; http://www.uoa.gr/; http://www.fhw.gr/; http://www.ssl.co.uk/
239 M-PIRO project partner the National Museum of Scotland is one institution that offers such a service.

nology specialists in each of the three languages, museum information providers, and system integrators with direct experience of working with museums. Previous experience with museum collaborators (in particular the **National Museums of Scotland**),[240] and ongoing contacts with museums standards efforts (through **System Simulation Ltd**) helped anchor the technology work in the real world.

© M-PIRO



M-PIRO's virtual reality display

The main NLP technique involved in M-PIRO is called *concept-to-text*. This involves turning logical representations of museum objects into natural descriptive texts. The project also dealt with speech synthesis, concentrating on the provision of natural intonation. The natural language generation system tailors the texts at various levels, including the choice of content, syntactic structure, and vocabulary; so a description intended for a child will use simpler sentence structures and words, and will not contain advanced information such as references to background academic texts. The system will also tailor the description depending on the history of a particular interaction, drawing comparisons with previously accessed objects where appropriate.

The natural language generation capability is integrated with three key technologies: authoring, personalisation, and speech synthesis. An authoring environment was developed to allow non-experts in NLP (such as museum curators) to input descriptions of the objects in a user-friendly manner. The authoring environment was tightly integrated with the NLP engine, allowing users to preview the kind of text that would be generated. The generation system was also integrated with personalised information stored externally on a separate server, allowing the system to draw on a user's existing knowledge when 'deciding' what to say. In general this meant that previously accessed information would not normally be repeated, maintaining the illusion of pre-stored personalisation.

Integration with speech synthesis was another of the M-PIRO project's central concerns. Text-to-speech systems are widely available, but all suffer from the problem of poor quality intonation. It is currently impossible to construct an automatic analysis of the syntactic, semantic, and pragmatic aspects of the input, which means that the intonation which the synthesiser uses is often badly formed. Generated texts can contain all of the required information, and the project has developed techniques for driving the synthesisers by marking the output texts with information specifically designed to produce the correct intonation. Thus, for example, when a new object is introduced, the synthesiser will add phonological stress to the relevant words, making the results more understandable.

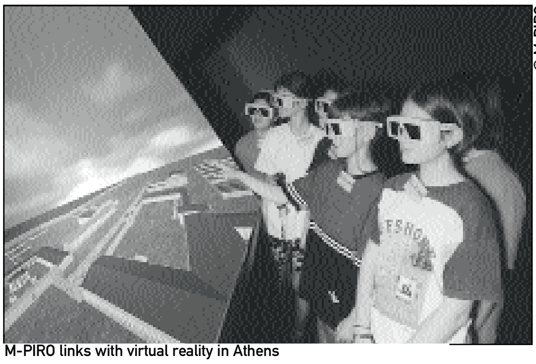
As with many NLP development systems, the crucial development personnel consisted of overlapping talents: programmers with knowledge of NLP issues, and computational linguists with experience of software development. The main M-PIRO project effort on generation, in Edinburgh, had exactly this mix of talents. This programming effort was backed up by scientific expertise which directed the main thrust of the research and kept

240 http://www.nms.ac.uk/

the developing system in touch with theoretical concerns in the area. The project's central NLP capability also benefited from the design of postgraduate projects on the generation of aggregation and comparisons. These are relatively complex linguistic features, and MSc projects on both topics were completed during the project's lifetime. One student was subsequently sub-contracted to integrate the new components with the existing system.

From the point of view of both the partners and the reviewers, the project was a success. The multilingual aspects of the research benefited greatly from the facts that the project was conducted at EU level and that collaboration between partners was so extensive. Principal investigators at the University of Edinburgh, Dr Colin Matheson and Dr Jon Oberlander, felt that the knowledge-based NLP approach assumed by the M-PIRO consortium was the only way to achieve the precise tailoring, according to user type and interaction context, which was the central objective. There is currently no alternative method of connecting language-neutral representations of content with multilingual text.

Three significant evaluations of the project have been carried out: two during its lifespan and one after its finish. Throughout the project, experts in the museum community checked the text quality and content for acceptability and accuracy. In the latter stages, its integrated authoring environment and text previewing capability were evaluated in a series of tests performed at the **Athens University of Economics and Business**.[241] The results showed that non-NLP experts were able to create and manipulate all aspects of the system with varying degrees of success but without serious problems. The main distinction was between texts which were structured using the aggregation and comparison modules and those which were not. Results showed three things: that English and Greek users believed that they remembered more of the structured texts, that they actually did remember more of the content, and that they enjoyed the structured versions better.



© M-PIRO

M-PIRO links with virtual reality in Athens

The M-PIRO team believes that the system represents the state of the art in a number of NLP areas. The basic language generation techniques are fairly standard, but the range of tailoring – in the language used, the selected content, the syntactic structure, and the lexical choices – is unique. The control over the international aspects of speech synthesisers is another first. While these are not 'core' NLP concerns themselves, they are only really possible with an underlying NL engine and represent a unique bridge between language generation and the kind of expressive language which is necessary to present cultural content in a believable manner.

The consortium plans to collaborate on future development, and a number of proposals for EU funding have been submitted. The main areas for investigation involve the inclusion of Information Extraction and scaling up the current demonstrator to handle large amounts of data. Matheson and Oberlander acknowledge that the system has a number of legacy aspects which make system maintenance and expansion by anyone

241 http://www.aueb.gr/

other than the development personnel extremely difficult.[242] However, it will be possible to use the existing demonstrator and technical project deliverables as the specification for a partial or complete re-write of the system and it is felt that this may be the best route forward. Currently, the demonstrator works with relatively small numbers of hand-input objects and one way to extend the range of material would be to extract the information automatically from existing databases. The consortium is therefore looking for funding to adapt existing multilingual Information Extraction techniques to create the language-neutral resources required for generation. The resulting large databases would present a challenge to some aspects of the language generation engine, and so the issue of scaling the system up represents another challenge.

Scenarios

Automatic labelling of objects by audience

A contemporary gallery wants to extend access to its collections to user groups such as young children, teenagers, and those without any prior knowledge of modern art. The curator currently finds the task of writing descriptive labels frustrating, as many subtleties of meaning she would like to include are lost in the process of making them accessible and comprehensible for all user types. The management's decision to make the collections even more accessible seem likely to lead to yet more frustration for the curator, as the labels will need to be simplified even further.

The curator has a friend in a computer science department at a local university who tells her about new developments in Natural Language Processing which allow tagged words to be altered according to a schema and, thereby, doctored to appeal to a certain readership. The curator sees in this the possibility for delivering attractive and useful information to less knowledgeable visitors without depriving the more experienced of nuanced descriptions that they are equipped to digest.

For the trial rollout, the curator begins writing full, detailed, curator-level textual descriptions of a selection of the gallery's most popular exhibits. The descriptions are written with strict attention to control vocabularies, which the curator finds to be a time-consuming task. She also finds being limited to a certain lexicon frustrating at first, and feels that the full descriptions are repetitive and very dry. However, the curator's friend reassures and reminds her that the full descriptive texts will not be seen by anyone except fellow curators: on the contrary, the texts delivered to the gallery visitors will be modified, targeted versions of the full descriptions.

After crosschecking against the control vocabularies, the curator's texts are marked-up and stored in a simple *MySQL* database. According to the profile of the user who is currently in front of a given painting, the full description is recalled, modified, and the appropriate version delivered to the user. For example, the curator level descriptions can be simplified and transformed into material suitable for a seven year-old child to comprehend by selecting alternative words where necessary – for example, *dada* becomes *nonsense*, a concept the child is more likely to understand – and the lengths of sentences and the description as a whole are restricted appropriately.

242 It should be stressed that the software development was for demonstration purposes only – there was no attempt to produce 'industrial strength' programs in the project. However, in terms of producing a working demonstrator only, the combination of the AI programming and linguistics work is ideal.

The tailored descriptions are delivered to small monitors positioned next to the artworks. Future planned developments include the delivery of other learning materials to these small screens, linked to the targeted labels. The user profiles can also be harnessed to help with delivering the object labels in text sizes, colours and fonts that the users will be most likely to find attractive an accessible; a form of skin technology.

This development also opens up the possibility of providing automatic visit summaries using radio frequency identification (RFID) tags to track visitor movements including links between the objects viewed and resources for further study. The NLP system proves to be a very valuable addition to the gallery's technological repertoire, allowing the curators a much-improved level of flexibility when sharing their considerable expertise across different platforms and user groups. A possible future development will be to expand the system to include text-to-speech delivery to mobile phone headsets via *Bluetooth*.[243]

Speech-to-text, with simultaneous automated mark-up, for an interactive visitor centre guestbook

The manager of a scientific heritage site is carrying out her annual informal appraisal of the visitor centre's attractions. Leafing through the visitor comments book located in the shop, she notes that many of the active and interactive displays have attracted praise and compliments. A visitors' book, however, seems a little archaic and incongruous in comparison with the shiny technological developments that surround it.

The manager consults colleagues and contacts in the sector on how they feel the feedback process could be enlivened and made more attractive to visitors who are, perhaps, uncomfortable with the written word. One of them suggests a more interactive experience, powered by speech-to-text technologies. Using a regular PC with basic software, a unidirectional microphone and a data projector, a system is designed to bring a significant amount of flexibility and fun into the feedback process. The unidirectional microphone is necessary to prevent ambient noise from a busy, nearby shop compromising the quality of the recorded speech. A keyboard is also included which allows users to type in non-standard words, which the software then associates with the phonemes to allow automatic vocabulary 'learning' for future recurrences.

After in-house testing (in which the staff thoroughly enjoys participating), the system goes live. Visitors are encouraged to speak their comments into a microphone and watch as their words are converted into nicely formatted text, incorporated into Flash animations and projected onto a large screen above the centre's entrance. A language filter is employed to prevent inappropriate language being used. This is a major advantage over the paper guestbook, which allows no automatic moderation and therefore requires frequent Tipp-Ex censorship from the manager.

The system is a hit, with feedback numbers doubling almost overnight. Visitors especially enjoy the interactive element that comes from the system's replies to their statements. Seeing their names and comments beamed in colour all around the shop is a magical way for young children in particular to remember their day out at the centre. The Flash animations can be linked with certain themes which illustrate and add value and meaning to the exhibits on show that day. The automatic learning functionality is popular with school-age children, who seem surprised and delighted when the system recognises their slang phrases and buzzwords.

243 For a early, real-life application of similar technologies see *ILEX* – Intelligent Labelling Explorer, http://www.hcrc.ed.ac.uk/ilex/

But the system's uses do not end with the projections above the exit door. The manager realises that the user comments could be repurposed for different features, both within the centre and on the Web site. With automatic mark-up applied to the comments at the moment of conversion from speech to text, the comments can be stored in a database and re-accessed online by the users for a given period after their visit. Particularly favourable comments can be re-purposed for publicity materials and Web testimonies. In time, the manager hopes to adapt the system to allow multilingual conversion, opening the feedback process to speakers of other major European languages.

Summarisation of digitised newspaper articles

Contextualisation is a currently one of *the* hot topics in the field of Natural Language Processing. Automated machine reading saves a great deal of time in research and can help identify useful and previously undiscovered sources for research and reference. It can also allow researchers to *exclude* irrelevant material quickly. In addition, distilled versions of much longer texts can be used to assist in studying the effects of textual artefacts on social and cultural history.

With all this in mind, a newspaper archive is interested in providing quick comparisons of different newspapers in times of conflict. The archivist is particularly interested in the vocabulary used by journalists of different political leanings and suspects that such a service would be of interest to other journalists, academics and Web researchers from all over the world.

In collaboration with a university computing science department, which provides the team with an able student as part of his postgraduate assessment/development, an algorithm is devised that works its way through a selected subset of the corpus, condensing each article into a single sentence or paragraph as required. The algorithm is designed to allow the user to define a set of keywords and the keyword vocabularies to be linked to thesauri imported from Open Source projects.

The summaries produced by the program can be presented in different ways for quick contextualisation. In time, the summaries themselves can be condensed further to form the basis of a visualisation in the form of a chart which outlines the political positions of different newspapers over designated periods of time. The subtleties of some newspaper propagandists had previously escaped scholars. Historical and political research could also benefit from closer (human) readings of material which had previously been considered fairly innocuous. This is of substantial benefit to critics presenting New Historicist and Cultural Materialist readings of literary texts. While the need to read the articles in full is by no means obviated, critics and researchers find a quick overview before starting close readings to be significantly time saving.

In time, the algorithm can be modified and expanded to cover other topic areas and vocabularies. It can be continually refined as different subject areas present different challenges. The basic framework is flexible enough to benefit researchers from a variety of disciplines and approaches. When the project team releases its work to the Open Source community it attracts a number of enthusiastic users from unexpected areas.

Using text-to-speech to improve accessibility to learning materials for in-house handheld devices

A natural history museum wishes to improve the accessibility of its collections for blind and partially sighted users. The museum already holds a large repertoire of learning objects, and has gained permissions for access to external resources, including Web sites and databases maintained by friendly organisations in other countries. The curators wish to merge and/or contrast some of these external materials with their own resources to enable a more seamless learning experience. Their fear is that producing audio versions of all of the resources one-by-one would be very time-consuming, would restrict the potential re-uses of the materials and would necessitate a near-impossible level of communication and cooperation between the different institutions. The curators also fear that an unacceptable amount of time would be lost in dealing with administrative work and translating materials between languages.

One of the curators looks into text-to-speech (TTS) technologies and, after consultation with experts in the field, he concludes that this would be an option worth exploring. There are a number of TTS technologies available on the market. After determining the minimum requirements the system would have to meet, the first decision the team has to make concerns which particular technology to deploy. While the museum's technical manager is highly supportive of the project, its funding is extremely tight and every cent counts. After consulting with experienced peers and colleagues, the project leader is directed towards an Open Source TTS application which meets the project's needs.[244] Although the system is less polished and sophisticated than some commercially available programs, the curator is aware that its Open Source status is likely to mean a broad and enthusiastic user/support group. Hence, he decides to go with this application.

The products of the TTS system are linked with existing learning materials using XML, allowing files to be re-purposed for a variety of different platforms. In time the system is extended to allow delivery of TTS to hand held devices as well, with headphones supplied by the visitor information desk staff in order to prevent disturbances to visitors who prefer the more traditional museum environment. The system is a success with visitors, and opens up more of the museum's treasures than ever before to a wider section of society.

Advantages and Disadvantages

Introduction

If we accept that knowledge cannot be shared without a common language,[245] every Natural Language Processing application must be fundamentally concerned with the transfer of concepts. In other words, the primary aim of NLP work should be the better understanding of cultural heritage sector materials and the delivery of content in ways that meet specific user needs as squarely as possible.

We now present a short list of the specific advantages and disadvantages, benefits and risks that the development of Natural Language Processing applications and techniques may hold for the cultural and scientific heritage sector. While a different list could be drawn up for each branch of NLP, the points below are broad, and intended to apply to the topic as a whole. The points which should be most obvious are (i) that NLP is of

244 Examples of such applications include *FreeTTS* (http://freetts.sourceforge.net/docs/index.php), Flite (http://www.speech.cs.cmu.edu/flite/), and *Festival* (http://www.cstr.ed.ac.uk/projects/festival/)

245 C.f. DAVENPORT T., L. PRUSAK (1998) Working Knowledge: How Organizations Manage What They Know, Boston, MA: Harvard Business School Press.

great benefit in terms of access to information, and (ii) that the variety and complexity of the approaches are likely to mean a steep and possibly intimidating learning curve.

Advantages

Improved access to information sources – The application of specialised information retrieval techniques leads to higher rates of recall during information searches. Indexing and summarisation methods save time and effort in searches for very specific information. The combination of these methods (in conjunction with semantic capabilities) leads to improved levels of precision and accuracy, minimised fallout and faster search times.

Focused, attractive and convenient access – The possibilities for reading untranslated texts in one's own language/dialect, or hearing explanations delivered at an appropriate level of detail, are attractive for all. They save time and effort compared to reading texts in foreign languages. Additionally, one's own language/dialect is the natural carrier for comprehension of content. This has been a major driving force in the study and improvement of human-computer interfaces and is a much friendlier means of delivery.

Building and accessing large, linked virtual collections – Natural Language Processing technologies facilitate the unification of scattered resources, both in geographic and in computer networking terms. The real challenges in this are in ensuring that materials collected together belong to the same class, are linked appropriately, and that the virtual collections are as complete as possible. Semantic Web technologies, in particular the use of ontologies, will play a large part in solving such issues in the near future.

Improved access for disabled people – Visually-impaired people benefit from the application of modern speech technologies. Hearing-impaired people can follow content delivered by an avatar through sign language, in conjunction with standard textual or multimedia material.

Disadvantages

Lack of user confidence – The new abundance of information sources can cause the feeling that something has been missed. Here, the quality of retrieval tools (and the linguistic knowledge incorporated in them) becomes crucial in ensuring users that search results are both accurate and exhaustive. In recent years, the importance of knowledge representation techniques has come to the forefront. This can play a significant part in providing an overview of topics and their interrelations.

The primacy of digital materials –NLP systems are (and seem likely to remain) restricted to materials available in digital form, thus missing printed material that is unavailable in digital format.[246] In networked/Web-based systems, users are unable to retrieve, access, and locate non-networked resources. The growing tendency to look for information solely on the Web without recourse to more traditional sources such as libraries may result in important documents being overlooked. For organisations that grasp the importance of 'going digital', crucial issues are the primary entry of materials, quality standards and the choice of appropriate encoding and mark-up standards. These lead to questions of digitisation and text entry, and the quality/accuracy issues that fol-

246 Copyrighted material presents further problems, and Intellectual Property issues in general are matters of which no content manager / provider can afford to remain ignorant.

low. Current EC priorities focus on improving access to digitised collections, not on the digitisation process itself. While many States have made important steps towards making their cultural and scientific heritage material available electronically, this is less true for most accession countries. As a result, there is a real danger that their voices will not be heard on the Web.

Issues of precision and recall – It is impossible to give precise and persistent measures of precision and recall for the Web due to its dynamic nature and the difficulties in searching the Deep Web. However, even if we imagine a static collection of 100,000 documents with 99% search precision, presentation of a lengthy list of irrelevant or partially-relevant results is unacceptable. Bearing in mind the fact that the average person can retain only seven objects in short-term memory, it seems outside normal human ability to absorb such quantities of data.[247]

Variety of approaches across different sectors – General-purpose ontologies are not suitable for specialised cultural heritage sector applications, necessitating the building of compatible topic-specific cultural ontologies. For this reason, it is important to promote innovative best practices and standardisation, despite the rapid (and potentially disparate) development of the technologies.

Potential divisions – NLP may contribute in narrowing the 'information literacy divide,' and to the 'digital divide.' The differences in access levels across information technologies, together with the effort and expertise required for the presentation of heritage materials, contribute to deepen the digital divide. Those who become skilled in the use of modern NLP and IR technologies will be increasingly successful in finding what they seek. Educational systems will need to be adapted to nurture the most essential skills in this respect, otherwise – even in countries where the digital divide is not pronounced – the potential for isolation through a lack of information literacy will grow.

Introducing the Technology

Selecting a Specification and Development Environment

The introduction of Natural Language technologies will require organisational management to produce a clear picture of the aims of the project. Issues which need to be clarified will include the following:

1. What are the fundamental aims of the NLP? Potential uses will include: offering resources in textual form in a single language; offering resources in multiple languages; offering tools for text/information retrieval; offering personalised documents to a variety of user groups and improving access to the less able. The last of these provides a further question: What will be the characteristics of the different user groups to whom the systems will cater? Such profiles will cover level of detail of information, appropriate sentence lengths, the use of specific terminology and levels of interest in specific topics.

247 http://www.aw-bc.com/DTUI3/lecture-notes/ch10-2.html

2. What particular technology best answers these needs? If an organisation is concerned about providing better means for searching its collections, the following considerations might help:

Type of search	Structured Query	Keyword	Natural Language
Tools	Formal query	Use of keywords; some knowledge of Boolean logic	Parsers
Applicability	Databases	Full text	Specific domains
Best for?	Restricted use: requires special training	Wide use; most people understand this type of search	Widest use

3. In what form is the bulk of the information which the organisation wants to be presented?
4. What NLP tasks should be involved? Will the system deal with the generation of content, its analysis, or a combination of the two?
5. Will access be offered to documents in written form alone, or will speech technologies be incorporated? If the latter course is preferred, what hardware will be necessary and how will this interface with existing systems?
6. Is it planned to offer tools for disabled users? What tools are best suited to this task?
7. What language(s) will be most familiar to the intended audience? Will it be necessary to provide translation in other languages and, if so, how accurate/graceful must the translations be?

Technological Infrastructure Issues

Apart from technologies which involve audio processes (such as Text-to-Speech and Speech-to-Text), most current NLP technologies do not require specific hardware and will run quite happily on a standard desktop computer. Most commercial applications, such as those used for machine translation, require investment in dedicated software and maintenance. If an organisation plans to obtain commercial software products, it would be wise to conduct research into the products, standards and quality requirements, as well as contacting comparable organisations that have implemented similar solutions. It would also be worthwhile to check whether there are organisations with similar existing resources and to investigate the option of building a shared, virtual collection.

Another important question is what information the organisation already has in electronic form, and what migration tools would be necessary for its reuse. It will be important to choose appropriate standards for digitisation, text-encoding and mark-up to an appropriate level.

Staff and Policy Issues

Natural Language Processing is as human-centred a technology as there is and, as a result, staff members will be of crucial importance in the developments, uptake and acceptance of NLP technologies. This is particularly so in projects concerning the collection of materials in digital form, and efforts should be made to ensure that staff members have access to attractive, straightforward and friendly tools for data entry and editing.

The following issues should be discussed in advance:

1. Are there specific linguistic levels which need to be processed: for example, is morphological analysis essential for the application? Do these require advanced skills from staff members involved in data entry and preparation? Will training be needed?
2. What will be the best and most efficient way to explain to staff and users what the system can and cannot do? How can this be made obvious within the interface?
3. How can staff and user frustration be minimised? Frustration often creeps in when a system is not intuitive and easy to learn. Should staff members and users be advised to scrutinise system results carefully, or should new software tools be developed which guarantee higher quality, potentially over a smaller subset of content objects?

INFORMATION RETRIEVAL

Executive Summary

Information Retrieval (IR) technologies have become almost ubiquitous in the presentation and use of cultural heritage content since the rise of the information network. IR is second only to email in terms of users' online activities, encapsulating everything from a Google search to data-mining the Deep Web, from automatic summarisation to personalisation of information, and from metadata to content-based multimedia retrieval.

These technologies are intrinsic to the reliable and efficient discovery and access of cultural content, especially over networks such as the World Wide Web. IR technologies now seem inseparable from the Web, which demonstrates both their necessity and their long-term effects on the way in which we seek and use information. IR and knowledge discovery technologies have revolutionised research methods and brought about a new mode of accessing digital cultural assets.

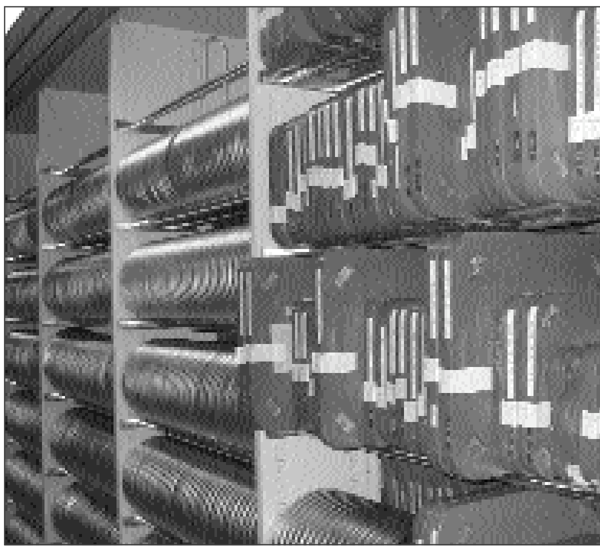
In technical terms, IR can be challenging. While a basic string search in electronic text is relatively simple, models for improving relevance, efficiency and accuracy are constantly undergoing development. Some text retrieval model approaches include defining relevance by number of occurrences, Boolean (matching logic constructions), vector (retrieving results from two overlapping results sets) and the 'Google-approach' (using hyperlinks to determine relevance). IR for non-textual media (without relying on metadata, i.e. content-based) is extremely complex and not yet reliable. Techniques currently in development include image colour analysis, audio or visual 'cues' in digital video, and shape recognition.

Innovative IR technologies such as content-based retrieval and summarisation will facilitate ever more efficient discovery of knowledge and digital objects, freeing the user from time-consuming, repetitive and error-prone tasks. Adoption of this technology is likely to have a lasting impact on the sector and, in the future, could reduce the need to attach textual metadata to digital objects.

Distributed retrieval and data mining are already widely used in the sciences and although case-based reasoning and agent architectures are universally applicable, they remain under-utilised in the cultural heritage sector. These methodologies could be beneficial to the preservation and use of cultural content but their potentials have not yet been fully exploited by the sector. To date, the cultural heritage sector has been most concerned with issues surrounding text retrieval, metadata and, more recently, content-based media retrieval.

Newer IR technologies are being adapted to increase the value of digital cultural heritage resources by:

- Increasing the accuracy, efficiency and reliability of basic searching/retrieval tasks;
- Providing new functionality in both text and multi-



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media searching (e.g. text summarisation, automatic segmentation of digital video);
- Freeing content from the metadata required for its retrieval;
- Enabling personalisation when searching resources;
- Unlocking the 'Deep Web' for knowledge discovery.

As succeeding paragraphs will indicate, Information Retrieval is a massive and ubiquitous subject area; issues of text representation and retrieval are both well established. There is a substantial overlap between this domain and that of Digital Asset Management, as covered in *DigiCULT Technology Watch Report 1* (p. 41-61). This report, therefore, focuses on the retrieval strategies rather than the functions of specific software packages although both will be of interest to cultural and scientific heritage decision makers whether as content providers or end users. New developments in content-based retrieval, once the technologies mature and can be reliably implemented, will have the potential to revolutionise the ways in which information is stored, organised, retrieved and reused.

The case studies featured in this report set some of the issues of IR in the heritage sector in context. *Progetto FAD* deals with the double-edged problem of making archival records accessible whilst simultaneously protecting the rights of each document. Finding very specific medical information in multiple languages by using patient records as queries is the subject of the second case study on the multi-national *MuchMore* project. The scenarios that follow show how IR technologies may be used to benefit institutions of various sizes across the cultural and scientific heritage domain, from the effective searching of Internet resources to new solutions for the retrieval of music and images.

An Introduction to Information Retrieval

Information Retrieval (IR) is a near-ubiquitous activity for any user of the Internet, electronic catalogues, databases, or computerised collections of any kind. IR technologies power every kind of automated search and, along with appropriate methods of data storage and representation, are vital to the access and discovery of information and materials.[248] With the exception of email, which has been driven up in recent years due to spam, information retrieval is the most common network activity. All readers are likely to have used some kind of IR technology, whether searching a library catalogue, browsing an image collection, or simply 'Googling' on the Web.

Information Retrieval is a relatively old technology compared with others covered in this report and it has been well explored and exploited by computer system users and developers alike. However, IR is by no means a static field; it must constantly adapt to the changing volumes, characteristics, and accessibility of information in the Information Age. Their ubiquity can make these technologies difficult to approach since they are considered by many to be a fundamental part of computer literacy. However, IR – perhaps more than any other technology we have covered – has a vast range of inherent diversity

248 See also the complimentary *DigiCULT Thematic Issue 6: Resource Discovery Technologies for the Heritage Sector* (June 2004), which concentrates on user-driven approaches in resource discovery. The position paper "Putting the Users First" by Guntram Geser, pp.7-12, gives an overview of current and future applications from the perspective of academic and educational users. Available online at http://www.digicult.info/pages/Themiss.php

in strategies, complexity, and development, from the simplest of computerised text comparisons, to innovation in the field of content-based digital media retrieval.

IR technologies have already had a huge impact on the cultural and scientific heritage sector, enabling users to access both specific information and discrete objects from the vast amount of data presented to them. However, some IR techniques are less mature than others and innovative solutions can be combined with older technologies to create new means for information discovery, presentation and personalisation.[249]

Background

A broad subject area, there are almost as many definitions of Information Retrieval as there are information retrievers. The term itself refers generically to "actions, methods and procedures for recovering stored data to provide information on a given subject."[250] In the cultural and scientific heritage sector, IR is particularly appropriate for the recovery of relevant information or media objects from large collections, the retrieval of information across diverse methods of storage and its meaningful presentation to the user.[251]

Information Retrieval is inherently linked to systems of storage and representation, but these topics are too large to be covered in any detail within this chapter and are instead mentioned only where they specifically relate to the IR technology in question. This report will also avoid a discussion of IR technologies within single storage, representation and recovery systems as this has previously been covered in other DigiCULT publications.[252]

History of IR[253]

Organising information in ways that will aid its eventual discovery is not a new technique. Well over 2000 years ago, Greek and Latin scholars included tables of contents at the beginning of their work and employed hierarchies of information such as chapters and sub-headings. Around 250BC, the Library of Alexandria offered an early catalogue system by means of *pinakes*, painted tablets or signs probably hung above the stored parchments. This system divided works into six poetic genres and at least five sections of prose – history, rhetoric, philosophy, medicine and law – each category alphabetised by author as a further aid. Variations on this system were used in libraries until the late 1800s when the organisation and placing of books became centred on subject rather than author. In 1876, American librarian Melvil Dewey published a "classification and subject index for cataloguing and arranging the books and pamphlets of a library," detailing a representation system to aid retrieval that is still used in libraries all over the world. It revolutionised book classification by attaching identity to the book (by means of decimal

249 DigiCULT's complementary publication *DigiCULT Thematic Issue 6: Resource Discovery Technologies for the Heritage Sector* (June 2003) is freely available online from http://www.digicult.info/pages/Themiss.php

250 For more examples try typing 'define:information retrieval' into the Google search box.

251 An excellent article on the more generic processes, situations, and science of information discovery is SOLOMON, P. (2002) "Discovering Information in Context" in *Annual Review of Information Science and Technology* vol.36.

252 See *DigiCULT Technology Watch Report 1*, Digital Asset Management Systems (pp. 41-61), available online at http://www.digicult.info/pages/techwatch.php

253 A good description of the development of information retrieval over the years can be found in LESK, M. *The Seven Ages of Information Retrieval* http://lesk.com/mlesk/ages/ages.html

numbering), rather than the shelf, and introducing the concept of relative rather than absolute positioning.[254]

In 1945, Vannevar Bush published an article envisaging quick access to all of humankind's accumulated knowledge and just short of 60 years later this dream is becoming a reality.[255] The information revolution brought with it the application of computer processing power to retrieval of documents and data, with two major distinct approaches: *analysis of information for retrieval* (e.g. using manual indexing or artificial intelligence for identification) and *statistical processing* (e.g. fully automated probabilistic retrieval techniques).

The 1950s saw the birth of the first information retrieval systems as we would think of them today. Early systems included the use of concordances (alphabetical listings of every word in the document), often in the form of KeyWord in Context (KWIC) indices. Specialist machinery such as Calvin N. Mooers' notched cards and the *WRU Searching Selector* began to appear, before digital systems gained popularity and rendered these specialist systems obsolete.[256] By the end of the 1950s, Hans Peter Luhn had described statistical retrieval and automatic indexing and in 1960, the probabilistic model of IR was founded.[257] The concepts of precision, recall, and evaluation for improving retrieval were defined shortly afterwards. The advent of computerised databases meant that indices could become far more detailed, and this (along with the growth of computer typesetting and word processing) led to free text searching, a task far more suited to computers than to humans. Systems such as *SMART* and *DIALOG* further developed IR techniques,[258] and by the late 1980s IR had been incorporated into some personal computer systems.

IR technologies were driven by changes in hardware. The steadily dropping price of storage discs facilitated time-sharing systems, leading to the information storage revolution of the 1990s. New technologies in turn prompted greater understanding of the techniques and methods of retrieval. The early 1990s saw the first large-scale information services utilising probabilistic retrieval,[259] multimedia storage in the form of databases, and, of course, the popularisation of the Internet and World Wide Web.

The Web explosion has had an immeasurable effect on both the demand for and supply of appropriate information retrieval technologies. As the amount of content available online steadily grows, so does the demand for effective information retrieval technologies. Moving on from free text searching, search engines have become virtually essential to anybody attempting to navigate the Web. Whilst the techniques first conceived in the 1950s have been refined and developed, more complex technologies (and representation standards) have evolved, often hand-in-hand with Human Language Technologies.[260] In order to increase the relevance of the results set, IR systems can now contextualise a search not only on the content of one specific query and the structure of the document but also on user profiles and preferences. Intelligent agents can be used to personalise retrieval, and the fields of information extraction, summarisation, and data mining con-

254 A detailed history of document retrieval within libraries can be found at http://pi0959.kub.nl/Paai/Onderw/V-I/Content/history.html

255 BUSH, V. (1945) "As We May Think" in T*he Atlantic Monthly* vol. 176, no. 1, July 1945, 101-108

256 More detail on the WRU Searching Selector can be found at http://www.libsci.sc.edu/bob/ISP/cwru.htm

257 MARON, M.E. and J.L. KUHNS, (1960) "On relevance, probabilistic indexing and information retrieval" *Journal of the ACM*, vol. 7, no. 3, 216 – 244.

258 For more information on SMART (System for the Mechanical Analysis and Retrieval of Text), see SALTON, G. (ed.) (1971) *The SMART Retrieval System: Experiments in Automatic Document Processing* Prentice-Hall, Englewood Cliffs, New Jersey. DIALOG can be explored at http://www.dialog.com/

259 For example, Westlaw: http://www.westlaw.com

260 See the section on Natural Language Processing, above.

tinue to develop. Information management systems are commonly used to facilitate searching online repositories,[261] and the first effective content-based retrieval systems (e.g. **IBM**'s *Query By Image Content – QBIC*)[262] have begun appearing on the Web. Some technologies are already ubiquitous in the digital age, while the potential for others in the cultural and scientific heritage sector is only now being discovered. Some of these, yet still in the developmental stage, have the potential to become influential, even central to the discovery of information, as digital media and the modern Internet mature.

Principles of IR

Whilst Information Retrieval is a wide and varied subject area, most IR systems rely on a few basic principles and assumptions. To consider the principles of IR best, it is important to define those areas and activities which are not strictly part of information retrieval, although there is necessarily an overlap.

(N.B. It would be outside the scope of this Technology Watch Report to discuss the indexing, storage, or representation of information. This is a large subject area in its own right and, although it is inherently linked to the retrieval of information, we will concentrate on retrieval technologies, only making reference to issues of representation where necessary.)

Browsing versus searching

The first distinction is that between browsing and searching. Both activities are user-initiated and can lead to the discovery of information, but they are approached in different ways and require different methods. When browsing, a user manually explores different areas such as directories[263] or Web pages, navigating between them to find the information required. The user is in control of the avenues to explore but has to adapt to the structure, naming conventions and design of the directory in order to guess correctly where the necessary information is located. The discovery process is slow in comparison with an automated search. However, thematically linked resources are grouped together, enabling users to locate much potentially relevant material at the same time. Browsing also facilitates the serendipitous discovery of information as users manually explore possibilities whilst iteratively refining or widening their initial query.

Searching, on the other hand, allows a user to specify a particular information need which, after being phrased or converted into a query language, is used by the computer to search for a document or item that matches the query within a specified information set. Searching utilises the fast processing power of the computer but it is the specifics of the query and searching algorithm that define the results, rather than the user. The goal of information *retrieval*, as opposed to browsing, is immediate random access to the data. Although both searching and browsing are valid means of discovering information, it is only in searching activities that technological information retrieval techniques are used.

261 *DigiCULT Technology Watch Report 1* covers Digital Asset Management Systems (DAMS) in detail. It is available online at http://www.digicult.info/pages/techwatch.php

262 http://wwwqbic.almaden.ibm.com/

263 Examples of popular online directories are dmoz Open Directory Project (http://dmoz.org/) and the Yahoo Web Site Directory (http://www.yahoo.com/)

Information and data

Another important concept is that of information versus data. Although often used synonymously, these terms have different meanings. Data are raw facts and, alone, have no inherent meaning. When these data are collected, structured, analysed or interpreted, they become information. Information is data in a usable form. It is important to note that data and information can operate in different modes; linguistic, visual, and auditory data are fundamentally different and the mode affects how we receive and understand them.

Consequently, information retrieval and data retrieval are slightly different tasks with different methodology and techniques. The table below shows some of the differences in the approaches to information and data retrieval.[264]

	Data Retrieval	**Information Retrieval**
Matching	Exact Match	Partial or 'best' match
Model	Deterministic	Probabilistic
Query language	Artificial	Natural (or as close to natural as possible)
Query Specification	Complete	Incomplete
Items returned	Matching	Relevant
Error response	Sensitive	Insensitive

Table 1 - Adapted from C.J.Van Rijsbergen, *Information Retrieval*, p.2.

The layer of interpretation required to turn data into information leads to some of the complexities demonstrated in the table: how do we achieve a 'best' match? How can we ensure a computer can 'understand' an incomplete query in a natural language? How do we define relevance? Answers to these questions will depend on the corpus (or corpora) being queried. Information retrieval strategies tend to be domain-sensitive, and the act of locating a piece of recorded music will differ greatly from finding its sheet equivalent. As we can see, IR is an art as well as a science.

Structured and unstructured information

Information and data both exist in structured (e.g. a standardised database) and unstructured formats (e.g. free text). This affects the approach to retrieval. Querying data within a database uses the system's knowledge of the structure and can be made very efficient. However, converting all information into a highly structured format is time-consuming, difficult and requires the application of standards such as mark-up languages or field definitions. String comparison techniques provide retrieval that is still possible with plain/unformatted text, and more complex retrieval methods are developing for the retrieval of other unstructured media.

Similarity as relevance

Perhaps the most fundamental concept within IR is that of *similarity* as *relevance*\ where a document's relevance is based on how similar it is to the query. A human being can

264 Table adapted from VAN RIJSBERGEN, C.J. (1979) *Information Retrieval (2nd Edition)* London: Butterworths, pp.2.

establish the relevance of an object to a particular query by assimilating and understanding its content and context. A computer has no inherent intelligence, therefore a model is required to define and quantify relevance. As this concept is at the heart of IR theory and practice, much past and current research on the improvement of IR systems is concentrated on the relevance model.[265]

For textual IR, similarity could be defined by matching a particular word or phrase (a string comparison) to a similar use of vocabulary in the document and the query or to text with the same meaning as the query even when words used may be different (semantic similarity). In other media, components can be compared in the same manner. For example, an image can be analysed to produce a colour histogram, which can then be compared to other histograms to retrieve images with the same colour palette. As this example demonstrates, *similarity* as *relevance*, whilst an excellent basis for an Information Retrieval system, is only useful in terms of the aspect under comparison – images with a high level of colour similarity, for example, may be completely different in terms of shape, texture and subject. The goal of any IR system is to retrieve as many relevant objects as possible, whilst avoiding including non-relevant objects in the results set.

Precision and recall

Another major concept in IR is that of *precision* and *recall*. "Precision" refers to the proportion of retrieved documents that are relevant to the query, while "recall" refers to the proportion of relevant documents that are retrieved. In other words, "recall" refers to how well the system finds what the user is seeking, and "precision" describes how well it excludes what the user is *not* seeking. Say, for example, a user searches for 'Schönberg' in a corpus of 1000 documents, twenty-five of which refer to the composer. If the search returns twenty documents, and only fifteen of these are actually relevant, this means ten relevant documents were missed, giving overall recall and precision figures of 60% (15/25) and 75% (15/20) respectively.[266]

For several decades, *precision* and *recall* have been the primary measurements which define the accuracy of an IR system. Testing different queries indicates an inversely proportional relationship between precision and recall in current IR systems; a very specific query will lead to a high level of precision in the retrieved results, whilst it may miss some documents which would have been relevant (low recall) – the converse is true for a vague query. This inversely proportional relationship is a practical (e.g. linguistic) rather than a theoretical constraint. The perfect IR system would have 100% precision and 100% recall but, partly due to the fact that retrieval can only be as good as the formulation of the initial query, this situation has yet to be achieved in a real word, large scale application.

It may be borne in mind that relevance can only be measured effectively by the person who carried out the search. It can change over time in different situations and for different users. Furthermore, a result's relevance cannot be defined as simply *true* or *false*. Objects may be completely, somewhat, slightly or not at all relevant. Computers cannot measure the relevance of a document to a user in a quantitive way although attempts at measuring precision and recall are being carried out as part of the US **National**

265 See VAN RIJSBERGEN (1979) pp. 6.

266 Of course the spelling issue of 'Schönberg' vs 'Schonberg' vs 'Schoenberg' may complicate matters here, potentially leading to lower levels of precision and recall.

Institute of Standards and Technology's Text Retrieval series of conferences (TREC).[267]

Exact match and best match

As its name suggests, the 'exact match' retrieval model returns results which satisfy a condition as true or false. For example, users searching for "this exact phrase" need to be sure that every document or object returned matches the condition. Information retrieval using the 'best match' model will return results in a non-binary state. Results do not have to satisfy precisely the query given and are assigned relevance scores by the IR system before being presented to the user, usually ranked by relevance. Whereas information (as opposed to data) retrieval systems are insensitive to small errors, retrieval systems based on exact matching will not return results which contain errors, no matter how small. A mistake in either the query or the data being searched will result in the object not being returned.

Whilst Table 1 (above) shows that exact match is used in data retrieval whilst best match is used in information retrieval, in reality the two techniques are often combined. Some studies have shown that expert users of IR systems prefer exact match to best match,[268] and that exact match can provide greater user control over what is retrieved, especially when searching very large sets.

Where IR is Currently Used, and How

As IR is such a large topic area, it would be impractical to provide a comprehensive view of where and how it is being used. Therefore, this report will concentrate on areas which are particularly relevant to cultural and scientific heritage: information retrieval from the Web, content-based multimedia retrieval, automatic summarisation and extraction, and multi- or trans-lingual information retrieval.

Retrieving Information from the Web

The World Wide Web is still the fastest growing part of the Internet. Web searching has become an activity natural to all kinds of researcher from IT specialists to schoolchildren. Presenting information online and enabling the general public to discover it became a necessary part of the development of any large institution or company after the Web explosion of the mid-to-late 1990s, and the rush to create online content (or to make existing content available online) powered this dot.com boom. Discovering content on the Web can take several different forms: using a search engine; searching an online catalogue; searching a specialised system or Digital Asset Management System;[269] and browsing through categories, directories, or following hypertext links.

There are hundreds of thousands of search engines, directories and link sites. It is estimated that these sites generate around 95% of all Web traffic and over 80% of referrals to

267 http://trec.nist.gov/
268 BYRD, D. and R. PODOROZHNY (2000) "Adding Boolean-quality control to best-match searching via an improved user interface" http://ciir.cs.umass.edu/pubfiles/ir-210.pdf
269 DAMS are covered in detail in *DigiCULT Technology Watch Report 1*, available from http://www.digicult.info/pages/techwatch.php

a typical Web site.[270] However, many of these search engines are restricted to one Web site (often "Powered by Google") therefore, in practical terms, the number of significant search engines is an order of magnitude less. Indeed, the top fifteen search engines generate over 90% of all search engine traffic. At the beginning of 2003, the search engines with the largest databases were **Google, AlltheWeb**, and **AltaVista**.[271] The search engine itself has become a competitive commodity, with many hundreds of Web pages such as *Search Engine Watch* and *Search Engine Showdown*[272] comparing the relative merits of each. Google planned to float on the stock exchange in mid-to-late 2004.

The Online Public Access Catalog (OPAC) is a Web catalogue of a library collection that is available to the public. Many libraries now make their OPAC publicly accessible via the Web, allowing users to retrieve information about collections directly from a library's Web site by means of relatively simple text comparison technologies. OPAC is merely one example of the thousands of online catalogues which present electronic records to enable users to discover information about tangible objects. However, as more and more collections are being digitised, and heritage institutions are increasingly cataloguing 'born digital' collections, a more specific type of system – a Digital Asset Management System (DAMS) – is needed to handle the representation, storage, and retrieval of these digital objects. Specialised systems of this type are numerous and varied, the precise technologies used being dependent on the needs of the collection and its users. However, at present most DAMS rely on the textual metadata attached to digital objects to retrieve them. The emphasis is on methods and means of *representation* rather than the retrieval algorithm itself.

Although valid and well-used means of information discovery on the Web, activities such as following the link structures of hypertext or browsing directories do not rely explicitly on IR technologies. These activities are initiated and carried out by user decisions rather than automatic retrieval algorithms and therefore will not be discussed in detail here.

The Semantic Web is the proposed successor to the World Wide Web, and will allow automated agents to garner *meaning* from Web resources, rather than just searching for text. In time, it is hoped that this will alter the dynamic between user and information in the IR process. It should be stressed that the Semantic Web is necessarily utopian; it is discussed in much greater depth in DigiCULT *Thematic Issue 3: Towards a Semantic Web for Heritage Resources*.[273]

Content-based multimedia retrieval

Early work on image retrieval began in the late 1970s, and has been a hot topic with IR researchers ever since. Initial methods concentrated not on visual techniques, but rather on the textual annotation of images for retrieval. However, automatic creation of meaningful annotations for sets of images is not (yet) feasible, requiring non-textual media still to be manually marked up. This is an expensive and time-consuming task.

270 A quick Google search for "search engines account for" revealed many different Web sites (of variable authority) quoting slight variations on these figures.

271 http://www.google.com/, http://www.alltheweb.com/, http://www.altavista.com/. Source http://notess.com/search/stats/size.shtml Some IR tools which collate results from other major search engines (known as meta-search engines) are http://www.metacrawler.com/, http://vivisimo.com/, http://www.copernic.com/

272 http://searchenginewatch.com/, http://www.searchengineshowdown.com

273 Available online at http://www.digicult.info/pages/Themiss.php

Since the popularisation of the Internet (and digital image and audio formats), the number of digital media objects has grown dramatically, highlighting the need for information retrieval techniques based on content rather text mark-up. Image retrieval technologies, although still not mature, have received significantly more attention than other media, namely digital audio and video. These three areas can be complementary in terms of research and development, however current work in each medium will be considered separately.[274]

Visual IR

Although not particularly well known, there are existing applications which, to various levels of reliability, retrieve images from large sets based on analysis of content. **IBM**'s *Query By Image Content* (QBIC) is currently being implemented at the **State Hermitage Museum** in St. Petersburg, Russia, to allow content-based access to its digital collection of world famous art.[275] Another system is *Surfimage* from the IMEDIA project at the **Institut National de Recherche en Informatique et en Automatique** in France.[276] *Surfimage* extracts low and high level features from images and uses the feedback from users to help define relevance for retrieval. *Blobworld* considers the colour and texture of segmented image regions (blobs) and allows a lot of user control over aspects of each blob to find matches.[277] *SIMPLIcity* (Semantics-sensitive Integrated Matching for Picture LIbraries) classifies images according to semantic differences, such as indoors or outdoors, before retrieving similar images based on statistical analysis of different regions.[278] Other European projects and experiments include *Collage, SCULTPTEUR*, and *ARTISTE*.[279]

© Penn State University

SIMPLIcity: Semantics-sensitive Integrated Matching for Picture LIbraries

Content-based IR has many applications beyond searching digital image archives. For example, aerial and satellite photos are vital for research in earth and space sciences, as well as the military. Examples of applications in other sectors include: facial or fingerprint recognition for security purposes; biochemical research e.g. DNA matching or retrieving similar molecules for experimental drug research; medical applications, such as diagnosis by visual recognition of abnormal tissue mass; advertising and design, such as selecting images to match a particular colour scheme, or providing a content-based online shop-

274 A good introduction can be found in AGRAIN, P *et al Content-based Representation and Retrieval of Visual Media: A State-of-the-Art Review* which is available online at http://www.sopinspace.com/~aigrain/MTAP.pdf
275 To search the museum's collection with QBIC, go to http://www.hermitagemuseum.org/fcgi-bin/db2www/qbicSearch.mac/qbic?selLang=English
276 http://www-rocq.inria.fr/imedia/, http://www.inria.fr/
277 Blobworld can be tried at http://elib.cs.berkeley.edu/photos/blobworld/
278 http://wang16.ist.psu.edu/cgi-bin/zwang/regionsearch_show.cgi
279 Papers on which can be found, respectively at http://www.archimuse.com/mw2001/papers/ward/ward.html, http://www.eva-conferences.com/eva/london/london2003/abstracts/GIORGINI.htm and http://www.cultivate-int.org/issue7/artiste/

ping catalogue to improve sales. Possibilities for future applications are wide-ranging. Some potential applications for the cultural and scientific heritage sector are: finding similar architectural shapes; discovering media pertaining to historical events for education or broadcasting; and developing the technologies for reliably discovering images from large collections and archives.

Audio Retrieval

Content-based retrieval of audio has traditionally received less research attention than image retrieval, but as an information carrier the auditory channel cannot be ignored. While audio analysis is used in a wide range of areas from criminal forensics to musicology, content-based audio retrieval applications remain somewhat limited. One example of a working system is *Soundspotter*, currently used by **Mitsubishi Electronic Research Laboratories** to develop *MediaFinder*, a new interface for searching large media collections.[280] *Soundspotter* uses pattern matching on audio feature vectors to identify the most similar sound files in a collection.

With the growing popularity of digital audio systems such as **Apple**'s *iPod*, the limitations of long text lists to describe collections are becoming more and more apparent. Other new interfaces for the retrieval of files from large corpora (a single iPod can hold 10,000 audio tracks comfortably, making users themselves into mobile corpora) are required to manage and access these comparatively huge amounts of data. Recognition techniques such as those utilised by **Shazam**, which allows users to identify songs using their mobile phones, are a first step in this direction.[281]

Bringing it together – IR of video materials

While techniques for audio and still image retrieval are reasonably well established, combining these two for the retrieval of digital moving images is still in its infancy. Although the subject of a great deal of research in recent years, much of this research has concentrated on automatic indexing and representation strategies such as automatic metadata extraction and segmentation, stopping short of developing actual new retrieval technologies. There are, therefore, still relatively few working applications for retrieving video by content. Institutions such as **IRCAM** and **Carnegie Mellon University**, with the *Informedia* project,[282] are furthering research and development in content-based retrieval of moving image materials. The *CueVideo* project, begun in 1997 by **IBM's Visual Media Management Group**, incorporates retrieval by content, utilising human language technologies.[283] The *Video Mail* Retrieval project uses language recognition on the audio tracks of video messages, and incorporates a content-based audio and video retrieval system.[284] *VisualSeek* provides colour and spatial querying similar to *QBIC* and adds, amongst other features, querying by motion for video clips.[285] Although not a fully-fledged content-based video retrieval system, the *European CHronicles Online* (ECHO)

280 http://www.soundspotter.com/; http://www.merl.com/projects/MediaFinder/
281 http://www.shazam.com
282 http://www.ircam.fr/, http://www.informedia.cs.cmu.edu/
283 http://alme1.almaden.ibm.com/projects/cuevideo.shtml See the section on Natural Language Processing, above, for more in this area.
284 http://mi.eng.cam.ac.uk/research/Projects/vmr/vmr.html
285 Although the Visualseek Java interface is available online at http://www.ctr.columbia.edu/VisualSEEk/, the system's test data are not available.

project presents a digital audiovisual library, utilising content-based techniques such as moving object and face recognition for retrieval.[286]

Other uses of Content-Based IR

As well as the obvious potential application of searching large collections without the need for descriptive metadata, there are other valuable uses for content-based retrieval. These include: the fast identification of previously recorded footage in the broadcasting industry for added functionality in home entertainment; the management of art galleries and museums, e.g. for visitor tracking; and retrieving media linked to Geographic Information Systems.[287]

Extraction and Summarisation

The growth in the number of digital document collections in recent years has already been mentioned as one of the factors driving IR development. The sheer amount of information potentially accessible is of huge importance to one particular subset of IR technologies: information extraction and summarisation. In common with other IR techniques such as searching, information extraction (IE) allows users more easily to access the objects most relevant to their needs. However, IE also provides the facility for integrating this information into an existing user environment. Extraction technologies differ from retrieval technologies: instead of indicating which objects are relevant to users, IE systems extract the relevant information from those objects, maintaining a link to the original document for reference.[288] Summarisation technologies amalgamate aspects of a document (which are identified by IE systems) in order to provide a more concise representation of its contents. An object summary can speed up the comprehension of the object for both IR systems and users themselves. An example of a basic summarisation tool is **Microsoft** *Word*'s 'AutoSummarize' feature. Taken together, these technologies are crucial to the production of high-speed, efficient IR systems for large amounts of data, and have great potential for the means of delivery of information to users.

When applied to textual media, these technologies are intrinsically linked to natural language processing, and are dependent to a large extent on the accuracy of NLP technology[289] Although this chapter mainly considers extraction and summarisation related to textual media, there is a great deal of overlap in the technologies of retrieval, extraction, and summarisation for multimedia objects. Automatic feature extraction from media with generally larger file sizes (images, audio, and video) allows the production of document representatives which greatly speed up the retrieval process. Another means of speeding up the retrieval process is by machine learning, whereby programs use a form of artificial intelligence to analyse frequent requests, associating search terms with popular resources. This can be as simple as basic statistical analysis or can employ more complex summarisation techniques. This topic is discussed more fully in the paragraphs on content-based retrieval, below.

286 http://pc-erato2.iei.pi.cnr.it/echo/ ECHO's Final Report describes the technologies used and can be found at http://pc-erato2.iei.pi.cnr.it/echo/documents/public/Final%20Report.pdf

287 See the section on Location-Based Systems, above.

288 More information on IE is available from the Proceedings of the series of Message Understanding Conferences (MUC) '94 – '98, and the still ongoing Text Retrieval Conferences (TREC): http://trec.nist.gov/

289 Some aspects of extraction and summarisation are discussed in the chapter on Human Language Technologies in this *Technology Watch Report*.

IE and summarisation are currently used in both research and commercial applications, most commonly in distilling information for intelligence agencies[290]. But their future potential for the education, medicine, commerce and heritage sectors or in the use of any large body of text, is immediately apparent. The EC-funded *FACILE* project provides a concept-based filtering and categorisation tool for financial texts (such as newspaper reports), while **Dialog**'s *NewsEdge* software provides an industry news extraction and summarisation service.[291]

On a more generic level, the *PROTEUS* project at **New York University** is developing an IE system for English, Japanese, Spanish, and Chinese texts.[292] In addition to extraction, **Teragram** claims that its *Summarizer* software provides a summarisation solution which can condense documents to various lengths (suitable for different output devices) in all European and Asian languages. There are many other similar products offered commercially on the Web.[293]

There are relatively few applications developed specifically for cultural and scientific heritage collections: the *General Architecture for Text Engineering* (GATE) has digital library applications; summarisation is discussed by the *Perseus Digital Library*, and *Informedia* has developed tools for summarising video data.[294] While mature European applications are rare, research continues across the world, and extraction and summarisation are hot topics for text-themed conferences, such as 2004's Document Understanding Conference series. [295]

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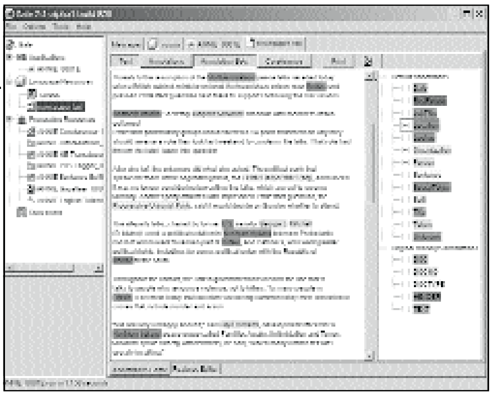

GATE: entity annotation

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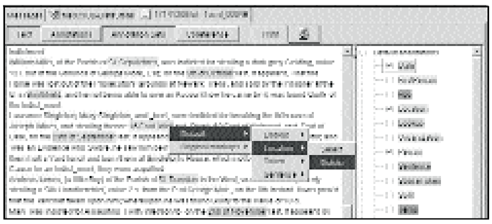


GATE: the Old Bailey digital library

In addition to their integration into IR systems, applications for extraction and summarisation in the heritage sector are wide-ranging. These include: clipping/highlighting of textual collections of any kind; the generation of natural languages from formal output representations; and automatic database population for analysis and research.

There is no clear boundary separating IR from extraction as the systems are so often merged. In a nutshell, IE can be thought of as 'understanding' the text, rather than just counting and manipulating words; in an ideal situation, IE could quickly deliver the most salient content of documents to the user, saving significant amounts of time.

290 For example, FASTUS http://www.ai.sri.com/%7Eappelt/fastus.html was developed in response to the needs of a government's intelligence community. Lockheed Martin http://www.lockheedmartin.com/, and MITRE http://www.mitre.org/ are two other examples of 'intelligence' systems.

291 http://www.quinary.it/pagine/innovation/resproj_frame.htm; http://www.dialog.com/products/productline/newsedge.shtml

292 http://nlp.cs.nyu.edu/

293 http://www.teragram.com/solutions/summarizer.htm

294 http://gate.ac.uk/; http://www.perseus.tufts.edu/Articles/jcdl2003.pdf, http://www.informedia.cs.cmu.edu/ See also "Enriching Perspectives in Exploring Cultural Heritage Documentaries Using Informedia Technologies," http://www-2.cs.cmu.edu/~wactlar/ACMMM02_Culture.pdf

295 For more information, see http://www-nlpir.nist.gov/projects/duc/pubs/2004papers/uleth.chali.pdf

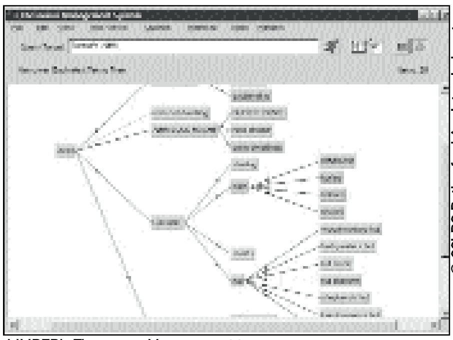
Translingual Information Retrieval

Information Retrieval in more that one language is particularly useful in Europe where valuable cultural and scientific heritage information can be inaccessible to users who do not speak the language in which it is presented. Due to the overlap with the chapter on Natural Language Processing, above, this topic will be discussed only inasmuch as it relates specifically to IR.

There are several successful European projects which facilitate trans- or multi-lingual IR. One of the first systems was developed within the European Multilingual Information Retrieval (EMIR) project between 1991 and 1994 and dealt with French, German and English retrieval.[296] This work was continued in other projects, and contributed towards the EXTRAKT linguistic engine[297] which is itself being used to facilitate other multilingual-focussed projects.[298] *Clarity*, based at **Sheffield University**, is an EU-funded project which aims to provide cross-lingual IR for text and audio documents with minimal reliance on translation. Techniques being investigated include organisation based on concept, identification of style and summarisation.[299] The *Cross Language Evaluation Forum* (CLEF) provides a means of testing IR systems for European languages; LIMBER (Language Independent Metadata Browsing of European Resources) supports multilingual access to Web data; and *PEKING* (People and Knowledge Cross-lingual Information Gathering) aims to provide cross-lingual knowledge management.[300] *Balkan WordNet* has developed a multi-lingual database of Balkan languages and is particularly innovative in its attempts to represent semantic relationships between words.[301]

Natural language question answering and fuzzy searches are now possible across language barriers. A list of approaches can be found in Claire Rémy's EUROMAP article, 'Natural Language Querying.'[302]

LIMBER: a multilingual user interface for European social science archives



LIMBER's Thesaurus Management tree

296 For more, see Stegentritt, E. (ed.) (1994) "German Analysis. Morpho-syntax within the framework of the free-text retrieval project EMIR" in *Computational Linguistics* no. 15.
297 http://www.textec.de/produkte1-eng.html
298 For example, PERTIMM: http://www.pertimm.com/ and VIAL (see http://www.content-village.org/articles.asp?id=609)
299 Clarity: http://www.dcs.shef.ac.uk/research/groups/nlp/clarity/
300 CLEF: http://clef.iei.pi.cnr.it:2002/; LIMBER: http://www.limber.rl.ac.uk/; PEKING http://www.interpeking.com/
301 Balkan WordNet: www.ceid.upatras.gr/Balkanet/ Many more projects and initiatives in cross-lingual information retrieval can be found on the DigiCULT Resources Web page: http://www.digicult.info/pages/resources.php
302 http://www.hltcentral.org/page-1094.0.shtml

How Information Retrieval Technologies Work

Introduction

Understanding the principles of IR, as briefly outlined above, will give readers a good initial understanding of the challenges behind effective information retrieval. Instead of considering the details of engineering an appropriate IR solution, this section will demonstrate how certain existing technologies work by using examples familiar to the heritage sector.

Information Retrieval Models

Many IR systems are designed on a generic model which abstracts the actual retrieval process. If the model is a good approximation of the real *ad hoc* retrieval situation, the conclusions it provides will be valuable and should lead to a clear and effective retrieval implementation.

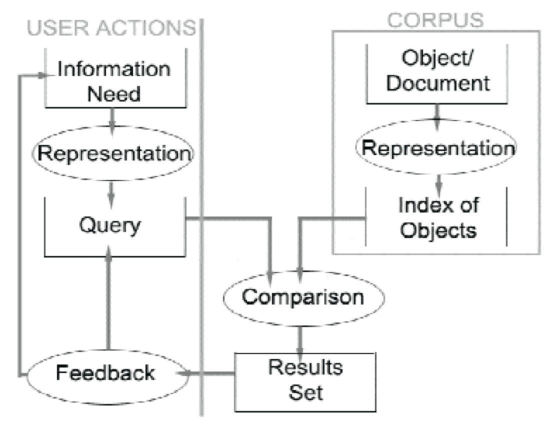


Figure 1 - A simple Information Retrieval model

This diagram shows typical components involved in an information retrieval task. A user has an information need which is represented in a query language of some sort (which could include natural language). Objects can represented by keywords, although this is not always necessary (e.g. for free text searching). In some IR systems, particularly when dealing with non-textual objects, the object representations are stored separately to increase the speed of the comparison process. Results are then returned to the user who may refine the query as a consequence. This report is not concerned with the representation and indexing portion of the diagram, but concentrates instead on the comparison algorithm – the process responsible for deciding which results are retrieved and which are excluded. This comparison process could comprise one or more different search strategies, as described below.

Components of a retrieval model depend on a typical use case scenario: the documents (at item and collection level), searching activity and the user. All these must be considered. For example, are the documents in different formats or different languages? Are they structured, unstructured or semi-structured (e.g. XML)? Are their subjects thematically linked or widely diverse? Who are the users likely to be? What is their likely search expertise? What is their range of knowledge about the documents and collection likely to be? Will they be performing in depth or trivial searches, or both?

Search Strategies

Boolean

Named after George Boole, the first professor of mathematics at **University College Cork**, Ireland, the term 'Boolean' refers to logical expressions, with variables which can only be *true* or *false*. Boolean "operators" such as AND, NOT and OR can be combined to produce very versatile conditions which can then be applied to a set of data. An example of a Boolean-type search is 'Samuel AND Beckett,' which will retrieve only documents containing both words, and 'theatre OR theater,' which will return documents containing either spelling.

Testing whether documents match these criteria (i.e. return a TRUE result) leads to very efficient searching. In fact, the clear, unambiguous formulation of Boolean queries has a number of advantages and works particularly well with expert searchers who know exactly what they are looking for. However, a TRUE or FALSE result by its nature produces an exact match rather than a best match from data and, therefore, has all the associated drawbacks of exact matching as described above. The Boolean strategy, whilst relatively simple to explain, can create problems for novice searchers, and the simplicity of the basic operators belies quite complex logic which can make query formulation a time-consuming and error-prone task. Boolean search systems tend to have a strong inverse correlation between precision and recall, limiting the theoretical ideal of absolute recall of completely relevant documents. The difficulty in producing an appropriately sized results set increases with the size of the collection. However, the predictable, highly controllable and efficient nature of Boolean searching means that it is still extremely popular and suited to many applications.

The most basic Boolean search does not rank documents according to relevance, but simply lists all those which satisfy the conditions of the query. However, the results of a Boolean query can be ranked and ordered by incorporating techniques such as the frequency of the query terms within a document, their relative proximity or their semantic importance. This produces a model which allows users to identify more easily the relevant documents but it is still only an exact match model. One further problem with the Boolean retrieval model is that, because the returned documents closely match expectations based on the query, it is easy for the user to overlook the fact that relevant documents may have been missed out – 100% recall is unlikely with Boolean systems.

Vector space retrieval

The vector retrieval model approaches the notion of similarity from a geometrical perspective. Its underlying assumption is that any text object (e.g. a document or a query) can be represented as a *term vector*, a line plotted in theoretical multi-dimensional space, where each term corresponds to one 'direction.' Each query and document are plotted as lines from the point of origin, and the more query terms the document satisfies the smaller the angle between document vector and query vector. Documents with lesser similarity will create a greater angle between the vectors; similarity is inversely related to the angle between them.

Vectors are linearly independent, i.e. the value along one axis does not imply any value along another axis. It is possible to include term frequency or 'importance' into the vector space model by altering the values along axes, but at its simplest the value is assigned to be 1 if the term is present in the document, and 0 if it is not. The following example uses three query terms (Shakespeare, theatre and Romeo) on three documents:

Contains?	Doc1	Doc2	Doc3	Query
Shakespeare	YES	YES	NO	YES
Theatre	NO	NO	YES	YES
Romeo	NO	YES	NO	YES

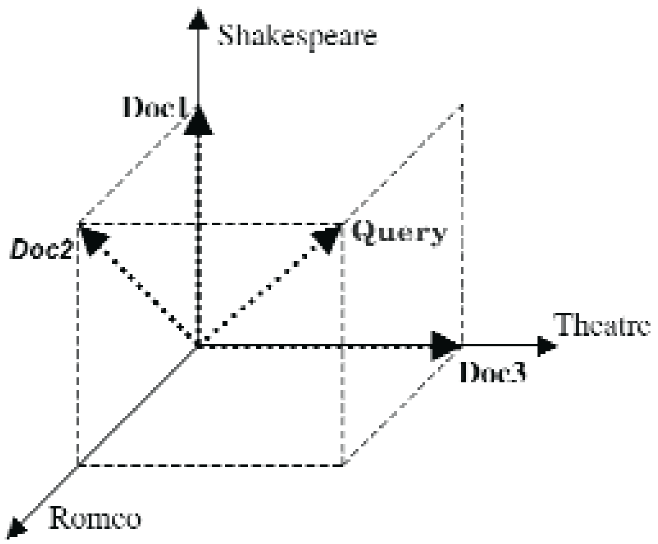


Figure 2 - A three-dimensional vector space, with three search terms

In three-dimensional space, the angle between the Doc2 and Query vectors is smallest, indicating the greatest level of similarity. If a document contained all three search terms it would occupy the same vector as the query, resulting in a difference angle of 0° – an exact match. This model can be extended into as many dimensions as there are terms in the query, leading to a robust determination of the best match.

The process of vector space retrieval was largely developed between 1960 and 1999 at **Cornell University** for the *SMART* retrieval system and is now the most common model used in contemporary IR systems.[303] Vector space retrieval allows users to enter free text queries with documents being ranked according to relevance. Unlike a Boolean search, this model will retrieve objects which do not match the search criteria exactly. The point at which an object is excluded for not matching closely enough will vary from system to system and relevance thresholds must, therefore, be set.

Probabilistic retrieval

Probabilistic IR relies on estimating probabilities for certain parameters, for example: the probability that a particular term occurs within a relevant document; the probability that the term also occurs in a non-relevant document; and the probability that the term is salient to the content of any document, regardless of relevance. These estimates are used to calculate the overall probability that a document is relevant to the query. The probabilistic model is currently less used than others, although it is claimed that it pro-

303 http://www.cornell.edu/ See SALTON, G. (ed.) (1971)

vides a more successful approach to dealing with the inherent vagueness of information retrieval.[304]

A note on Relevance Feedback

Relevance feedback is not a model for information retrieval itself, but an important part of many models. Human evaluation of a results set fed back into the model, addresses one of the basic problems of IR – that relevance is subjective, semantic, and task- and user-dependent. This prevents an automated process from ever being able to judge reliably whether a returned object is, in fact, relevant. As demonstrated on the generic model diagram, above, users can redefine their information needs and queries by drawing conclusions about the relevance of the results set. However, relevance feedback is formally included in many contemporary IR systems to improve the retrieval algorithm interactively. This is particularly useful in content-based retrieval systems, where relevance is often much more difficult to define than simply matching a text string[305] For example, when searching a set of images by content, a user may be asked to define each image as relevant or non-relevant to a query. These data are then incorporated into the IR system and considered next time a query returns those particular objects. With enough data on what other users found to be useful (or not useful), the automated process can act intelligently in selecting a results set and eventually improve both the precision and the recall of the searching algorithm.

Document Representation

The scope of this work is not to cover methods and standards of object representation, but since representation is important to the understanding of retrieval, a brief introduction to relevant methods is outlined below. The most familiar means of representing objects is through metadata. The highly structured nature of metadata, their limited length and small range of likely values (especially in the case of controlled vocabularies) allows retrieval models quickly and efficiently to search the content *representative* (i.e. descriptors) of an object rather than the content itself. However, as most readers will be aware, comprehensive metadata are the ideal rather than the norm. In terms of IR, two important principles of producing metadata are those of *exhaustivity* and *specificity*. Broadly defined, "exhaustivity" refers to the number of different topics indexed, and "specificity" is the exactness of the description of each topic. Metadata with high exhaustivity leads to high recall and low precision, whereas low exhaustivity produces a results set which is precise but has low recall. The converse is true for levels of specificity.[306]There are other types of document representative which may be less familiar. One example is a matrix representing the frequency of different words within a text file which can be quickly checked to assign relevance based on term frequency.

304 For a detailed description of the probability model, see FUHR, N. (1993) *Representations, Models and Abstractions in Probabilistic Information Retrieval* http://www.is.informatik.uni-duisburg.de/bib/xml/Fuhr_93.html.en

305 Approaches in personalised search and implicit feedback mechanisms are described in Joemon M. Jose "Personalisation Techniques in Information Retrieval", *DigiCULT Thematic Issue 6: Resource Discovery Technologies for the Heritage Sector* (June 2004), pp. 22-26. Available online at http://www.digicult.info/pages/Themiss.php

306 See VAN RIJSBERGEN (1979), pp. 24.

Summarisation tools can be used to produce shorter representatives of documents, which are searched in place of the full text. Non-textual documents have various means of representation: images can be represented by colour histograms, shape vectors, and regional divisions (either as images themselves, or as numerical data). A video stream could be represented by a single frame, or by a 'summarised' sequence of data. Audio can be analysed to produce a graph of volume or pitch levels over time. These methods are designed to reduce computational time when performing a retrieval task. Like all metadata, an object representative is only useful in so far as it accurately describes the contents of the object itself, even if this is limited to one particular type of data (e.g. colour).

Text Retrieval

As David Blair states in 'Information Retrieval and the Philosophy of Language,' "the retrieval, primarily, of documents or textual material – is fundamentally a linguistic process."[307] Most readers will be familiar with the searching and retrieval of text documents (e.g. digital files with .txt, .doc, or .html extensions) as a day-to-day task. The following paragraphs outline the major methods used by IR algorithms to improve both precision and recall in text retrieval systems.

Term frequency and weighting

A common basis for an IR model is the relevance of a document in direct proportion to the number of occurrences of the search term(s). Gauging relevance purely by frequency has its disadvantages; longer documents are likely to be judged more relevant since they contain more words overall. If two results have the same score, the shorter document is often preferred as it is more focused on the query topic. This model is therefore often extended to include document length into a similarity score.

This model can be further refined. The assumption behind term weights is that not all of the words in a document are equally indicative of its overall content and meaning. Each term is assigned a score based on its estimated importance. Documents containing words defined as important are given a higher score and are ranked as 'better' matches. Of course, the success of this system depends on how importance is estimated. Term weights can be simply calculated from their frequency of occurrence in the document, and the number of documents in which they appear (i.e. their specificity to a particular document), normalised by other factors such as the length of the document. Importance can also be assigned semantically. For example, a term appearing in the title or subheadings may be given greater weighting. Finding a word using a linear search can be inefficient in large datasets, so a representative of the entire dataset is constructed in the form of a matrix which indexes words and the document(s) in which they appear. This matrix can be very large and is likely to be sparsely populated, with relatively few words occurring many times, and a lot of words only once. (In reality, even this method can become inefficient and an inverted index may have to be produced instead.) This statistical infor-

307 BLAIR, D. (2003) "Information Retrieval and the Philosophy of Language" in *Annual Review of Information Science and Technology* vol.37 pp. 3. This article demonstrates many of the IR difficulties raised by the idio syncrasies of language.

mation can be used to aid the definition of importance for term weighting.[308]

Manipulation of query terms

Querying text will always include some aspects of natural language processing. Several techniques exist for manipulating query terms, to improve either the efficiency or the accuracy of an IR system. Assuming that a system is performing a comparison on a document representative rather than on the free text of the document itself, the rules which are applied to produce the representative must be considered when implementing the search. Defining exactly what constitutes a 'term' is integral to a good IR system, and the following issues are useful to consider even when searching free text:

- How to handle punctuation – e.g. does E.U. become EU?
- How to handle numbers – e.g. should digits be represented as text or vice versa?
- How to handle different cases – e.g. are capital letters ignored, even when they occur in the middle of a sentence?
- How to handle different morphological forms of the same word? 'Stemming' reduces all forms to the term root; for example, 'compresses', 'compressing', and 'compression' are all stemmed to 'compress.' Stemming is not unproblematic, however, as searching for 'neutralisation' may return documents about neutrons, and some stems are not identical (e.g. absorb from absorption).[309] A similar technique is "lemmatisation", a process that amalgamates words into the same base form, for example, 'am, 'are', and 'is' are all forms of the verb 'to be.'[310] This process can be made more precise by reversing it, i.e. generating a list of all morphological variants of the basic form for comparison.
- How to handle ambiguous word 'tokens' – e.g. should a phrase like 'state-of-the-art' be treated as a single term/token?

More computationally expensive options include using thesauri to handle synonyms, and automatic spelling corrections, known as fuzzy searching.[311] This allows for alternate spellings, but can slow the query by up to a factor of one hundred. Obviously, a spelling correction when applied to a search query will not identify documents containing spelling errors unless the error has itself been corrected in the document representative. Fuzzy searches are particularly useful when searching a corpus that is likely to include errors, such as documents batch-captured using optical character recognition (OCR).[312]

Beyond individual terms

The use of quotation marks in systems such as **Google** allows whole phrases to be

308 For a more detailed account, see SALTON, G. and C. BUCKLEY (1988) "Term-weighting approaches in automatic text retrieval" in *Information Processing & Management* vol. 24, no. 5, 513 – 523

309 See VAN RIJSBERGEN (1979)

310 The problem is, of course, not limited to English. The German and French equivalents, *sein* and *être* respectively, are equally irregular, with declensions bearing little resemblance to the infinitive.

311 For a discussion of how to use thesauri and other knowledge organisation systems in Web-based resource discovery see Douglas Tudhope and Ceri Binding "A Case Study of a Faceted Approach to Knowledge Organisation and Retrieval in the Cultural Heritage Sector", *DigiCULT Thematic Issue 6: Resource Discovery Technologies for the Heritage Sector* (June 2004), pp. 28-33. Available online at http://www.digicult.info/pages/Themiss.php

312 Some contemporary models make use of fuzzy logic as well as fuzzy terms. An article praising this approach can be found at http://searchenginewatch.com/searchday/article.php/2158571

defined as a single token. Concatenating individual terms in this manner is a useful technique, especially for extremely large datasets, but will exclude any phrase which does not provide an exact match. A more advanced technique is that of proximity searches, for example, finding documents where 'Madonna' occurs *near* to 'Raphael.' Proximity searches require position indexing for each term, and are consequently more computationally intensive, and reliant on appropriate document representatives. Automatic detection of document structure can facilitate 'zoned' IR, for example, a query could be limited to terms occurring in a certain chapter, or in the zone identified (via SGML/XML markup, for example) as the author's name.

Web searching

IR on the Web faces a particular challenge in that the dataset is immense, ever changing, and not standardised. The fact that Web content and formatting is in a constant state of flux means (a) that IR system searches are based on incomplete information, (b) the huge amount of online information can result in an unmanageably large answer set, often with very low precision, and (c) the highly interlinked but non-standard structures of the Web can result in loss of structural meaning since a results set does not preserve hyperlink structures.[313] Most significant of these problems is the high number of pages likely to be returned from a query, which presents difficulties in ranking the results for users seeking the 'best' Web page for their information needs. In August 2004, **Google** reported indexing around four billion distinct Web pages. Documents and studies from various other sources demonstrate the speedy growth and change of this information set.[314]

As online information is so predominantly text-based, Web IR uses the techniques developed for text retrieval: quotes, fuzzy searches, and Boolean logic. The exact approach will vary from system to system; there is no single definitive method for the retrieval of online information.

Search engines

The term 'search engine' can be applied to human-created directories such as the collaboratively-compiled *dmoz* Open Directory Project, which claims to be "the largest, most comprehensive human-edited directory of the Web"[315]. Nonetheless, the term is now generally understood to refer to 'crawler' based systems, or a combination of the two approaches. A crawler, or spider, is a program which automatically generates links by visiting a Web site, 'reading' it, following its links and adding the site to the search engine index. Web pages are 'crawled' on a regular basis, perhaps once every couple of months, so that changes can be reflected in the index. The third part of a search engine is the software which actually retrieves pages from the catalogue and ranks them according to relevance. Most search engines use quotation marks to identify a phrase and Boolean

313 Details on the structure of the Web and link analysis can be found in BAR-ILAN, J. (2004) "The Use of Web Search Engines in Information Science Research" in *Annual Review of Information Science and Technology* vol.38. This article also presents an evaluation of search engines and methods of appropriately clustering or ranking retrieved results.

314 See RASMUSSEN, E. (2003) "Indexing and Retrieval for the Web" in *Annual Review of Information Science and Technology* vol.37

315 http://dmoz.org/

"operators" as words or mathematical symbols, e.g. AND, +, NOT, -, OR, etc. Use of the OR operator can retrieve a great deal of non-relevant results and, therefore, most current systems use AND or NEAR (a restrictive AND which includes proximity detection) instead of OR to improve the precision of results. Boolean queries can be "nested" using parentheses, for example: *habitat AND (cat OR feline)*, which is equivalent to combining the results of the queries *habitat AND cat*, and *habitat AND feline*. However, novice searchers may have difficulty with this language so a more intuitive Advanced Search page is usually provided with forms for query terms and options such as "must contain all of these words" or "must contain the exact phrase." A powerful feature included in some major search engines such as **AltaVista** and **Google** is the ability to restrict a search to (or exclude results from) one particular domain. Therefore the query *Louvre +host:fr* will retrieve all pages contain the word Louvre which are held at any French domain. This technique is extended to various other specific 'zones' e.g. *title, URL*, and *site*. Some search engines also support 'wildcards', a character (often an asterisk) which can represent any letter(s). Therefore, *mo*se* would query for *moose, mouse, Morse*, and even *morose*.[316] Similarly, the tilde symbol (~) can often be used for synonym searching.

Of course, not all Web IR is based on searching free text. Just as digital images, audio, and video can be retrieved using their metadata, so can Web pages. HTML includes some meta tags which can hold attributes such as page titles and keywords.[317] Search engines use this information to find pages, and to determine their ranking order.[318]

Web IR by browsing

Search engines are not the only means of information discovery on the Web. Hyperlink structures facilitate browsing for information, but while links can be arranged hierarchically to create a straightforward directory-like structure, this is not the norm. Two means of finding information on the Web via a combination of searching and browsing are *authorities* and h*ubs*. Working on the assumption that creating a link to another Web page functions as an endorsement of that page, "authorities" are pages which are linked to by many others. "Hubs" are pages which provide a lot of referrals to other pages, giving out many endorsements. A well-known and respected hub is often the starting point for information discovery by browsing. The vast array of hyperlinks in the Internet are used to calculate *PageRank*, the global ranking system at the centre of **Google**'s proprietary technology, where the number of links to and from pages add to their perceived value to searchers.[319]

316 A table of search engines and their supported features can be found at http://searchenginewatch.com/facts/article.php/2155981

317 Meta tags are described on the excellent W3Schools site, http://www.w3schools.com/html/html_meta.asp, along with details of how best to use them to aid Web page discovery.

318 More information on how different search engines work, their strategies, and how best to use them is available at http://searchenginewatch.com/facts/index.php In particular, Danny Sullivan presents a description of ranking in his article "How Search Engines Rank Web Pages" at http://searchenginewatch.com/webmasters/article.php/2167961

319 For more information see http://www.google.com/technology/. Interested readers could also refer to KAO, B. and D. CHEUNG, (2003) "Information discovery on the World Wide Web" in FENG, D., W.C. SIU, and H. ZHANG (eds.) (2003) *Multimedia Information Retrieval and Management* London: Springer

Content-based multimedia retrieval

Whilst the retrieval of text by content is relatively simple using the methods described earlier (and those in the section on Natural Language Processing, above), content-based retrieval of other media formats is more complex. Non-linguistic visual and auditory channels are entirely different from written language in terms of communicating meaning. An image can communicate different meanings both *iconically* (i.e. it looks like something you recognise), and *symbolically* (e.g. colours can create emotional effects). Audio, too, has various ways of presenting information across time. Spoken language, music and noises at different speeds, volumes and pitches are understood differently. Audio-visual material combines these complications and adds more, such as the 'language of film': camera moves, cuts, the juxtaposition of different shots and voice-overs. The diversity within these information channels is reflected in the complexity of retrieving the information.

Although a common technique of multimedia information discovery is category browsing – 'guessing' a category and looking at or listening to each item, hoping to find the one you want – this does not fall into the definition of a retrieval technology. Methods of content-based IR can, therefore, be split into three main areas:

- Query by concept – e.g. find media where the content is water;
- Query by 'sketch' – by creating a simplified version of the information need, e.g. drawing a literal sketch for images/video, or singing a tune to retrieve recordings of that tune;
- Query by example – providing the system with something which is similar to your information need e.g. an image/photograph of a cat, in hope of retrieving more like it.[320]

Images

Content-based IR uses different techniques based on different aspects of the image: colour, shapes, position within the frame, textures, even text detection and recognition.[321] The technique used will depend on the nature of the collection. For example, a collection of black and white photographs and a set of Mannerist paintings will require quite different approaches. Comparing different aspects of the image can affect system performance in different ways; similarity measures are often combined to determine the ranking order of results, the best match being the image with the highest cumulative similarity score across the aspects analysed. Combining various techniques and analysis of high and low dimensional visual features for the best results is a tricky balancing act, often domain specific, and dependent on the set of images being searched. There is currently no 'best' solution for content-based retrieval.

As with textual retrieval, object "representatives" can be used to speed up the search,

320 This technique is also used in Web searching; some search engines offer a "More like this" feature to help users refine their query.

321 One application of automatic text and shape detection which is particularly relevant to heritage professionals is in searching for images which contain a trademark, watermark or other mark of ownership. For more information, see EAKINS, J. "Trademark Image Retrieval" in LEW, M. (ed.) (2001) *Principles of Visual Information Retrieval* London: Springer-Verlag

alleviating the need for computationally expensive, 'on-the-fly' analysis. Visual contents can be extracted and represented by multi-dimensional feature vectors which are stored in a database and compared for similarity. In addition to purely visual content, images can contain semantic content which is more complex to interpret. For example, a frame of a comic strip may derive some of its meaning from its relationship to other frames.[322]

Invariance and discrimination

In the same way that "exhaustivity" and "specificity" are important for retrieval of text, a good content descriptor should strike a balance between *invariance* and *discrimination*. "Invariance" refers to how recognisable the content descriptor is, e.g. can the system correctly identify a tree even in different lighting conditions and from different angles? However, the more invariant the descriptor, the less it is affected by external factors and therefore the less discriminative power it has. A highly invariant tree content descriptor would probably retrieve all images of trees, but might also retrieve images containing bunches of flowers, green cars and even buildings, giving high recall but low precision, whereas a highly discriminative content descriptor would only retrieve relevant images, but is almost certain to exclude many images of trees that are widely different from the comparator, giving high precision but low recall. The best point of balance is limited by current technology, but even if this limitation is ignored an 'ideal' content descriptor is highly dependent on both the idiosyncrasies of the collection and the needs of its users.

Content descriptors can be acquired at different structural levels. A global descriptor uses the visual features of the entire image, but by splitting the image into arbitrary regions (e.g. equal tiles) or semantically meaningful areas (e.g. faces, or ground and sky) local descriptors can be produced which more accurately represent the image content.

The most extensively used content for image retrieval is colour information. As each pixel in a digital image can be described by three values (red, green, and blue), it can be represented as a point in 3D space, known as the colour space. This allows comparisons between colour distributions in different images by, for example, the computation of a colour histogram. Histograms characterise image colour content particularly well at both global and local levels and are robust enough to handle changes in the scale, angle and rotation of the image. Another more complex technique is the production of a colour *correlogram*, which analyses the spatial correlation of pairs of colours. As this process facilitates the detection of edges in the image, it can be used to define semantically meaningful areas within the image automatically. Research and development of systems that include retrieval by invariant colour features are under way, but care must be taken that the invariance does not reduce discriminative powers beyond a useful level.[323]

Although an intuitive concept to humans, texture within images is not automatically recognised from its content and must be defined as a repeating pattern of variations in colour or intensity. Texture can be measured statistically by considering properties such as contrast between nearby pixels and the 'randomness' of their distributions, or "entropy". Texture analysis can also be performed using modelling techniques where a pattern is defined based on estimated parameters resulting in the reproduction of the conjectural

322 For a description of contextual image retrieval, see SRIHARI, R.K. and Z. ZHANG (1998) "Finding Pictures in Context" in IP, H. and A. SMEULDERS (1998) *Multimedia Information Analysis and Retrieval Proceedings of the IAPR International Workshop*, MINAR '98 Hong Kong August 13 – 14 1998.

323 For more information, see GEVERS, T "Colour-Based Retrieval" in LEW (2001) and Chapter 2 of DEL BIMBO (1999) *Visual Information Retrieval* San Francisco: Morgan Kaufman Publishers

texture. Pattern recognition like this does not work well on natural textures, which tend to be more chaotic and do not conform to a particular model. The final approach is structural, where the texture is defined as a two-dimensional pattern consisting of primitive shapes arranged according to a set of placement rules.[324]

Unlike colour and texture comparisons which rely on intensity, *shape matching* uses geometric visual features and remains one of the most difficult aspects of content-based image retrieval. Shapes in images can be formed by boundary detection – i.e. by means of discovering colour values that describe lines or edges in the image – or by region-based methods. Shapes are then represented as a set of features which characterise the global form of the shape and local descriptors. A good shape descriptor should be unaffected by transformations such as rotation, scaling, and movement within the image. Shape detection and retrieval is not yet reliable and requires domain-specific knowledge to produce successful results.

Analysis of visual aspects such as colour and shape within the overall *structure* of an image can provide useful data for content-based retrieval. For example, while sky and sea areas may have similar colour histograms, their relative positions in an image will usually determine the areas of blue most likely to be sky or sea. The relationship of different shapes can help indicate whether a particular image is relevant to a query.[325]

Audio

Audio can include such different channels as speech, music and other sounds. It can be retrieved based on factors such as melody, volume, timbre and other acoustic features, or by semantic features such as voice recognition.[326] As with visual information, audio is subjective and can be extremely difficult to describe in words.[327] The same difficulties in computation time, the variety of approaches and the need of domain-specific knowledge can all be applied to the aural channels.

Content-based retrieval of audio often starts with the classification and segmentation of the data. Discrimination between music, speech and other types of sounds is generally not difficult. The detection of segments (e.g. separating speech from silence, laughter, or applause) within audio is possible with current technology. A hierarchical system for content-based retrieval allows aural data to be coarsely classified at first (e.g. as speech or music) before sub-division and statistical analysis is performed on the acoustic features.

Feature analysis is performed on one aspect of the audio data to produce feature vectors – e.g. measuring and plotting volume on a graph against time elapsed – before a comparison is performed by pattern-matching the resulting vectors. An alternative is to analyse the pitch of the sounds, producing a 'map' of the melody. This can then be transformed into another format. Audio analysis systems often treat an identified tune as a series of musical intervals rather than exact notes, meaning a melody can be retrieved regardless of the key and octave in which it is played, and sometimes regardless of tempo. As early as 1995, systems were able to reach high levels of accuracy in

324 For more information, see SEBE, N. and M. LEW "Texture Features for Content-Based Retrieval" in LEW 2001) and Chapter 3 of DEL BIMBO (1999)

325 For more information, see VELTCAMP, R. and M. HAGEDOORN "State of the Art in Shape Matching" in LEW (2001) and Chapters 4 and 5 of DEL BIMBO (1999).

326 Voice recognition is discussed in more detail in the section on Natural Language Processing, above.

327 In the words of Declan McManus, "writing about music is like dancing about architecture."

identifying melodies and retrieving matches from small datasets.[328] Innovative modern audio recognition and classification software uses Support Vector Machines, 'intelligent systems' which map input into a high-dimensional feature space and can be 'trained' to perform retrieval functions.

Digital video

Techniques developed for image and audio content-based recognition are now being applied to digital video and other moving image media formats. Each frame of a video can be treated as an image for retrieval purposes and the soundtrack treated as an audio file. However, moving image material is an extremely highly structured medium, more so than either still images or sound. The structural elements of each document can be used to both improve image and audio recognition technologies and to create new approaches to effective retrieval.

Because digital moving images consist of a series of slightly different digital images (and sounds, potentially), a vast amount of data are required and much is redundant since each image differs only slightly from its neighbours. This facet of the medium can provide valuable tools for content-based retrieval. For example, shot boundaries ('cuts') can be detected by comparing two consecutive frames. If they are very different it is likely that the shot has changed. Another useful characteristic is that a series of very similar images can be taken as a group to identify content. With a single image, random factors such as image 'noise' can disrupt the recognition of objects within the frame, whereas random factors are reduced when dealing with a large number of images depicting similar content. Not only are individual frames related, they can also be analysed alongside the soundtrack. For example, a selection of pixels might be more easily identified as a face if accompanying sounds have been classified as speech. The fact that a digital video is treated as a structured document rather than an unrelated series of images with sounds attached is highly beneficial to its retrieval by content.

As well as structure, video has semantic channels of meaning; for example, a montage of different shots can describe or imply meaning above and beyond the content of each individual shot. Technologies for content-based video retrieval[329] bring together several previously mentioned technologies: natural language technologies; image recognition for automatic production of metadata from video materials; extraction and summarisation; annotation via speech recognition, segmentation of the footage by identification of key frames, and retrieval of frames by content.[330]

Video can include more complex editing techniques which complicate the process of key frame identification by detection of shot boundaries. Whilst a sharp transition is relatively easy to identify, a gradual transition such as a fade or dissolve, or spatial transitions such as wipes, present more difficulties to the detection of shot boundaries and are more error prone.

For video indexing purposes, document representatives are often produced using auto-

328 See GHIAS, A., J. LOGAN, and D. CHAMBERLIN (1995) "Query by humming – musical information retrieval in an audio database" in *Proceedings of ACM Multimedia Conference* San Francisco http://www.cs.cornell.edu/Info/Faculty/bsmith/query-by-humming.html

329 The Informedia project is a good example of this: http://www.informedia.cs.cmu.edu/

330 Fore more detail on how some of these techniques work, see ASSFALG, J. et al (1998) "Embodying Semiotic Cues in Video Retrieval", LAM, C.F. and M. LEE (1998) "Video Segmentation Using Color Difference Histogram", and WEIXIN, K. et al (1998) "A New Scene Breakpoint Detection Algorithm Using Slice of Video Stream" all in IP and SMEULDERS (1998).

matic summarisation technology, different for this medium from that for text.[331] Extraction and summarisation of video materials use many of the same techniques as content-based retrieval. Although it is generally agreed that high level 'aggregates' of video are almost always necessary, decisions regarding the level of granularity of segmentation will affect the accuracy of retrieval; whether a coherent 'story' can be gleaned from specific footage will depend on the method used. Different techniques include summarisation by shots, scenes (e.g. one episode/story in a news programme), camera movements, specific characteristics (e.g. the shot – reverse shot progression used widely in fiction), and segmentation by sound.[323] As with content-based retrieval for other media, relevance feedback plays an important role in improving the search algorithm and increasing the efficiency of the system.

Extraction and Summarisation

Whereas IR tends to perform retrieval using statistical methods, treating each document as a 'bag of words,' extraction aims to use relevant media processing techniques to look inside this bag in order to capture the information held within objects. IE techniques can actually reduce the effectiveness of IR systems if they are inaccurate or inappropriate, but they perform complementary functions to retrieval and are particularly suited to question answering and summarisation tasks. IE of text relies more heavily on Human Language Technologies than IR, since not only the content but also the *meanings* of sentences must be accurately captured.[333] The basic model of an extraction system is a *template*, a linguistic pattern which allows the system to capture 'facts' from the text. Techniques such as attribute value pairs, and noun, name, or date identification are used to break down the natural language into a form more easily understood by automatic systems. These templates are domain specific to some extent and research is ongoing into making a single system that can be widely adapted across a diverse set of material and genres.[334] At a higher level, IE relies upon the structure and positioning of text (e.g. sentences, titles, and clauses). Semantic understanding is the subject of much contemporary research. Texts are generally processed in sequential phases from lexical and morphological processing and word identification to syntactical analysis and the ultimate extraction of relevant events and relationships. The same principles can be adapted to create IE systems for non-textual media.

There are two main approaches to building an IE system: firstly, by 'knowledge engineering' (a hand-built, domain specific system); and secondly with an automatically trainable system reliant on statistical methods and incorporating feedback from users. The two models are suited to different situations. Knowledge engineering gives excellent performance within the domain or genres for which it was designed but it relies upon the

331 Summarisation and extraction of text is discussed in more detail below. Video extraction and abstraction is one of the areas covered by the MoCA project: http://www.informatik.uni-mannheim.de/informatik/pi4/projects/MoCA/

332 Content-based video retrieval is covered in detail in Chapter 6 of DEL BIMBO (1999). See also SMEATON, A. (2004) "Indexing, Browsing, and Searching of Digital Video" in *Annual Review of Information Science and Technology* vol.38.

333 See VOORHEES, E. (1999) "Natural Language Processing and Information Retrieval" in PAZIENZA, M. (ed.) (1999) *Information Extraction: Towards Scalable Adaptable Systems* London: Springer

334 See WILKS, Y. and R. CATIZONE (1999) "Can We Make Information Extraction More Adaptive?" in PAZIENZA (1999)

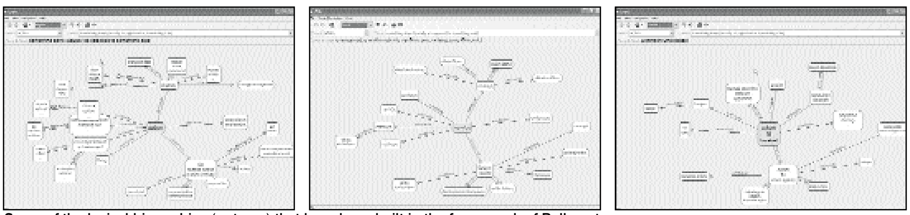
expertise of its creators (which may not always be available), an existing corpus, and a certain amount of fine-tuning. This type of system is extremely time-consuming to build and, therefore, expensive. The 'intelligent machine' approach can learn from annotations and feedback. It is therefore customisable and more portable but initially needs to be trained using a set of appropriate data that can be expensive and difficult to find.

Summarisation uses the features extracted from objects and reassembles them as a "representative" of the object as a whole. There are many parameters which define how a summarisation system works and how the information contained within each summary is presented to users. Summarisation systems may have varying levels of granularity (e.g. whole sentences, phrases, or just salient words) and can produce summaries as a fraction of the whole object while aiming to lose as little meaningful content as possible. The compression ratio is one of the most important parameters for summarisation. Summarisation systems can amalgamate the contents of several different individual objects or simply summarise one item.

Decisions on how to present the summaries themselves are also numerous. Should a summary present extracts of the source (for example, a whole sentence) or an abstracted version of the source (e.g. image feature vectors)? Should it be *indicative* (i.e. describing the topics addressed in the source document), *informative* (i.e. offering conceptual coverage), or *critical* (where the summary presents a 'position' on the source document)? The summary may be connected text or simply a fragmentary list of phrases. It can be personalised by individuals, or focussed on particular groups of users. All of these differences must be reflected in the model used to analyse and transform the original text (IE technologies) and synthesise the summary.[335]

Multilingual Information Retrieval

Multilingual IR uses many of the same techniques discussed above. In essence, a source document is analysed to extract all instances of the query terms. These terms are then matched using multilingual lexical knowledge bases, and further refinement can fix the meaning of each term more clearly. This word-sense disambiguation bridging system allows for greater accuracy when attempting to define terms as being equivalent. Classification of text is often based on phrases rather than individual terms as this can utilise more sophisticated NLP techniques to discern meaning. Projects such as *Balkan WordNet* aim to produce semantic links between words in different languages, allowing the retrieval of information from a linguistically diverse set via a single query.[336]



Some of the lexical hierarchies (or trees) that have been built in the framework of Balkanet.

335 Details of summarisation systems, how they work, and how they can be used can be found in MANI, I. and M. MAYBURY (eds.) (1999), *Advances in Automatic Text Summarization* London: MIT Press

336 See SOMERS, H. (1999) "Knowledge Extraction from Bilingual Corpora" in PAZIENZA (1999). This topic is covered in more detail in the section on Natural Language Processing, above.

Information Retrieval and the Heritage Sector

Information Retrieval technologies are already particularly prevalent within the heritage sector. Every collection of materials large enough to make browsing impractical will utilise a search facility: from library catalogues, to massive image databases, to the 'Search this site' link in many institutional Web sites. IR technologies are an indispensable part of the dissemination of information resources by heritage institutions and projects. It is not a case of persuading these organisations to use IR – this is a given – but rather in demonstrating how the technology can best be used for the most effective and rewarding results. The following paragraphs present suggestions for situations in which IR could be used for more innovative solutions than simply by searching a collection.

One search for widely dispersed content

One of the major problems users face when seeking something specific is the risk of searching in the wrong place. A Web search partially addresses this problem with a dataset of widely diverse materials from dispersed sources. However, IR still will not retrieve results from Web pages containing content dynamically generated from information held in databases. Heritage applications in particular store a huge amount of data in the 'deep Web,' and mining this information is the subject of a great deal of research.[337] A user looking for a particular image in a digital asset management system (DAMS) will retrieve no useful results if the image is not present, nor will there will be any clue as to where else to look. This problem is beginning to be addressed with new distributed image retrieval solutions which allow users to apply their search to several different resources at the same time.[338] Growing emphasis on standards means that collections are likely to become more compatible and interoperable in the future. It will become possible to connect different systems and datasets so that one search can cover numerous resources. This is a difficult problem to tackle in terms of co-ordination and funding as well as technology, but the carefully planned use of standards and DAMS will increase the possible uses to which IR systems can be put across different resources.

Time savings

A major feature of effective IR systems is their ability to save time for users. Not only can IR technologies save a great deal of browsing time, especially in the extremely large collections associated with the heritage sector, but the comprehension of a document or object can also be sped up using information extraction and summarisation techniques. The increasing use of intelligent IR agents means that user preferences and needs can be more specifically defined, delivering more focused information to individuals. In this way, systems open up new vistas for users, particularly in providing or increasing access to otherwise 'hidden' artefacts, data, documents and objects.

337 The future of discovering the deep Web is the subject of Alex Wright's article In *search of the deep Web* available online at http://www.salon.com/tech/feature/2004/03/09/deep_web/index_np.html

338 See S. Berretti et al "Collection Fusion for Distributed Image Retrieval" *Lecture Notes in Computer Science (LNCS 2924)*, Springer-Verlag, pp. 70 – 83, *ACM SIGIR Workshop on Distributed Information Retrieval*, Toronto, Canada, August 2003.

Reducing the metadata burden

A great deal of time and money is spent discussing, designing, and implementing systems for object representation in collections. This work is currently necessary in order to make the digital artefacts accessible via IR systems. While there will always be a need for certain types of metadata (e.g. for preservation, administration, and contextual or conceptual information), accurate content-based IR systems reduce the absolute need for the most difficult and error-prone aspect of metadata: actually describing the object and its contents.

Content-based IR not only reduces the laborious processes involved in creating very detailed descriptive metadata, with incalculable savings in curator time and organisation funds, it also creates a new point of access for users. A user may have a clear visual memory of an art image but no idea of its title or artist and little domain knowledge to allow a guess for keywords. The user's only hope using metadata-based retrieval is to keep guessing keywords or hope to stumble across the image whilst browsing – infeasible with large collections and/or slow Internet access. A content-based IR system could allow retrieval based on memory of image colours, shapes, composition or textures.

Of course, there will always be a need for descriptive metadata: even the best content-based IR system cannot identify abstract concepts like love, victory or success as humans can. However, some of the burden of producing descriptions can be bypassed, errors and ambiguities caused by the idiosyncrasies of the metadata can be reduced . The linguistic representation system –inherently different from non-textual media – does not have to be the only point of access users have to collections of objects.

Accessing 'impossible' content

Content-based IR partially solves the problems posed by a collection without metadata and which would otherwise be impossible to access by search methods. Just as a textual query on an image will be unable to retrieve results unless information in a matching channel is provided (i.e. metadata), the same query will have no further success in retrieving materials which are written in a different language. Cross-lingual IR technologies can solve this difficulty but the source text would be presented in its original language which may be incomprehensible to users. Combined with language translation technologies and text recognition techniques, IR could in the future facilitate the retrieval of information and present it in the user's language and in full, highlighted, summarised or quoted text based on the chosen subjects or keywords.

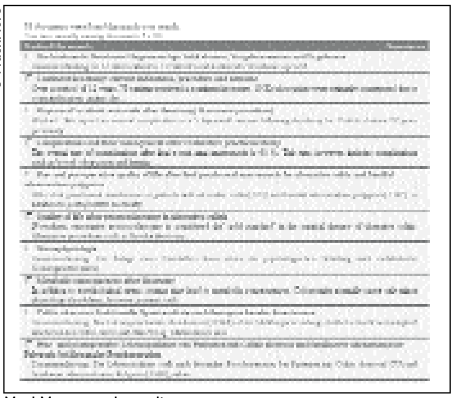
Scientific or philological analysis

The retrieval of complete objects and the extraction of information within objects can provide valuable data for linguistic, numerical, visual, and aural analysis. Potential heritage applications are diverse: automatic database population by identification of defined 'fields'; studies of the language of fiction through time and across society; study of the use of colour in a particular genre of painting; examination of the use of televisual techniques in news broadcasting; development of more realistic synthesised sounds; or analysis of astronomical data and photography.

Case Studies

MuchMore (Multilingual Concept Hierarchies for Medical Information Organisation and Retrieval)[339]

© MuchMore



MuchMore search results

MuchMore provides a framework for developing new approaches to *cross-lingual information retrieval* (CLIR) for the medical domain via the integration and refinement of technologies. The very large ontologies of domain concepts and extensive corpora that already exist within the medical domain have influenced the project's work towards the refinement, integration and comparison of concept-based retrieval methods and corpora-based approaches. To achieve the goal of a cross-lingual information retrieval framework, MuchMore focused on the following aims:

- The effective combination of both heterogeneous resources and retrieval approaches, and their integrated use for multilingual information access and management. This includes performance evaluation based on realistic information access tasks;
- Research and development concerning the effective use of multilingual concept hierarchies, together with the automated acquisition of domain-specific linguistic resources;
- The demonstration of a cross-lingual information access prototype system, providing access to multilingual information through the combined use of corpus analysis and a domain-ontology.

Modern medicine is evidence-based and, as such, demands a constant update of information regarding new diagnostic and therapeutic methods and strategies. In this respect, *MuchMore* offers a solution in automatically providing relevant information, independent of language, according to a patient history.

The **MuchMore** consortium comprised coordinators **DFKI GmbH, Language Technology Department**, Saarbrücken, Germany, specialising in linguistic/semantic annotation, sense disambiguation, and relation extraction; **Eurospider Information Technology AG**, Zürich, Switzerland, working on corpus-based CLIR and performance evaluation; the **Xerox Research Centre Europe (XRCE)**, Meylan, France, which dealt with research and development in corpus-based CLIR and term extraction; **ZInfo** (Zentrum der Medizinischen Informatik) at the **Klinikum der J.W. Goethe Universität**, Frankfurt, Germany, specialising in user requirements and user evaluation; the **Language Technology Institute** at **Carnegie Mellon University**, Pittsburgh, USA, experienced in corpus-based and classification-based CLIR, summarisation, and performance evaluation; and the **Centre for the Study of Language and**

339 This case study is based on an email interview with Dr Paul Buitelaar of **DFKI – Language Technology**, Saarbruecken, Germany. The interview took place in July 2004. http://muchmore.dfki.de/

Information (CSLI) at **Stanford University**, Stanford, USA, whose research areas include sense disambiguation, relation extraction, and corpus-based CLIR.[340]

ZInfo, the partner with the most expertise in user-centric methods, supplied the project with insight on user requirements from the medical field. The consortium organised an international workshop with experts from medical informatics, information access and natural language processing in order to ensure that the goals of the project were considered from a wide perspective. Advice from this range of experts was useful in shaping approaches to the project's work.

To achieve a solution to information needs in this area, and to provide a multilingual information management and access system, existing methods (semantic annotation, similarity thesauri, example-based translation, pseudo-relevance feedback, document classification) and resources *(UMLS (Unified Medical Language System), MeSH (Medical Subject Headings), EuroWordNet)* were combined with technologies newly developed within the project. From the starting points of concept-based (e.g. semantic annotation of terms and relations, including disambiguation and filtering) and corpus-based approaches (e.g. similarity thesauri, example-based translation, pseudo-relevance feedback, and classification) and combinations of the two, the project researched and developed further solutions. The new solutions stemmed from a necessity to integrate methods for further accuracy in CLIR, as well as in extending standard user functionality. These extensions led to new options for uploading electronic patient records with automatic support in (multilingual) query construction, automatic, interactive (multi-document) summarisation.

MuchMore produced a prototype for medical cross-lingual information retrieval that integrates these hybrid approaches, combining corpus-based (i.e. use of statistics and machine-learning) and concept-based (i.e. use of knowledge bases) methods, including semantic annotation and automatic thesaurus construction. The prototype uses CLIR to allow the retrieval of medical scientific abstracts in both English and German, using a patient's record as a query. A sophisticated query construction tool sits on top of a meta-search engine providing access to a merged and ranked list of relevant documents from three different search engines that implement cross-linguality in different ways.

Semantic annotation in the refined MuchMore approach is based on linguistic pre-processing (part-of-speech tagging and morphological analysis), and includes sense disambiguation to map ambiguous terms to the most appropriate concept, together with term and relation extraction to extend existing knowledge bases where needed. Semantic annotation of UMLS terms [341] had a positive effect on precision and recall in CLIR tasks. Sense disambiguation of the same terms had a slight effect on average precision figures, whereas semantic annotation and disambiguation of EuroWordNet terms showed no positive effects.[342]

340 http://dfki.de/lt; http://www.eurospider.com; http://www.xrce.xerox.com/; http://www.zinfo.de/; http://www.lti.cs.cmu.edu/; http://www-csli.stanford.edu/. The personnel breakdown was as follows: DFKI – 1 full-time manager, 2 full-time researchers, 1 part-time researcher; CMU – 1 part-time manager, 3 part-time researchers; CSLI – 1 part-time manager, 1 full-time researcher; EIT – 1 full-time manager/researcher; XRCE – 1 part-time manager/researcher, 1 full-time researcher; ZINFO – 1 part-time manager, 3 part-time researchers.

341 http://www.nlm.nih.gov/research/umls/

342 http://www.illc.uva.nl/EuroWordNet/

© MuchMore

MuchMore: terms and semantic relations

© MuchMore

MuchMore: terms and semantic relations, plus hierarchy

The extraction of bilingual term pairs from parallel and comparable corpora provided good results. The most significant approach in term extraction from comparable corpora is in the use of existing knowledge bases, in this case UMLS and MeSH.[343] CLIR experiments with extracted term pairs showed an increase in both recall and precision, although precision dropped when more than five (top) translation candidates were included as term pairs.

Relation extraction remains a very difficult topic of research, reflecting the intensive involvement of domain experts in development and evaluation of relation extraction systems. In experiments on the filtering/disambiguation of extracted relations, no positive effect was found on the CLIR task. On the other hand, the extraction of new instances of *existing* relations showed an increase in both precision and recall.

Automatic thesaurus construction methods – including similarity thesauri and example-based translations – consistently gave good results in CLIR tasks. Nevertheless, the best results were obtained in combining these with existing (manually constructed) knowledge bases such as UMLS and MeSH. All of these technologies were integrated in the prototype.

Ongoing performance testing provided quantitative feedback on the performance of different methods and resources. The MuchMore project has been successful in showing the advantage of the combined use of knowledge-based and data-driven approaches in cross-lingual IR. The prototype system produced results with higher precision at the top-level of retrieved documents and can satisfy information needs more efficiently. Evaluation has shown that, from the user's point of view, medical experts were interested in the different functionalities provided by the MuchMore prototype, particularly the query construction tool, meta-search engine and summarisation tool. The query construction tool provides the novel functionality of formulating a query interactively from an uploaded electronic patient record. The meta-search engine allows the user to combine different search methods without the need to know the technical details of the methods used

The project ran from July 2000 to June 2003, with a total budget of €1.5M. Future work will be primarily concerned with dynamic approaches to the development and maintenance of knowledge resources, i.e. thesauri and ontologies. The final report of the MuchMore project was published in June 2003, and is available from the project Web site. [344]

343 http://www.nlm.nih.gov/mesh/meshhome.html
344 http://muchmore.dfki.de/pubs/D0.6.final.pdf

The Vikings Project[345]

The Vikings storyboard search utility plus media playback

© University of Oulu

The Vikings Project was set up in order to develop new content-based retrieval systems for searching databases of moving image and audio material. As larger and larger amount of material is stored in archives, powerful search robots become more and more important. One problem of current retrieval technology is that audio and video material must be annotated extensively before exact matches can be hoped for. Methods must be developed to automate off-line annotation and make annotation-free online search operations effective. The purpose of the present project is to research and develop new algorithms for making these automatic annotations possible. This means that pattern recognition algorithms must be implemented which enable content-based search and analysis of stream-based material.

The project was performed by **MediaTeam Oulu** research group in cooperation with the **Technical Development Centre of Finland, Institute of Electronics (VTT Electronics)**.[346] VTT Electronics has high-level competence in audio signal processing and video retrieval technologies. The main goals of the project were:

- To create core methods for the content-based retrieval of multimedia data. Core methods refers to the essential pattern recognition algorithms that are used for content analysis of media in order to classify and understand the content. Audio recordings are analysed in order to, for example, recognise the period during which a desired piece of music is played, or to find the start and the end of a conversation. Speech recognition is applied to recognise key words or specific speakers in a recording. Text analysis can be applied for finding pieces of text that discuss a specific topic of interest. Video retrieval requires image analysis for identifying specified events in the scene, for example, the appearance of a specific person. The techniques and algorithms for achieving these results were the focus of the project.
- To create novel language technology by combining the disciplines of linguistics and information engineering. Speech recognition methods will be developed in which Hidden Markov Model-based phoneme recognition (a linguistic pattern identification technique) is enhanced with rule-based language models. Discourse analysis methods are developed with which it is possible to indicate the points of time where a discussant changes in a recording. This will be based on changes in signal dynamics derived from prosodic characteristics (i.e. rhythmic characteristics, or the way each phoneme is said) of different persons. Techniques of text analysis using computer linguistics are developed to aid topic-based text retrieval.
- To demonstrate the developed methods and technologies as new services on a distributed multimedia platform. The project's aim is not only to explore existing meth-

345 This case study is based on an email interview with Vikings Project Manager Tapio Seppänen which took place during August 2004. The Vikings Project Web site can be found at http://www.mediateam.oulu.fi/projects/vikings

346 http://www.mediateam.oulu.fi; http://www.vtt.fi/ele/

> ods and develop new approaches, but also to demonstrate prototypes of new service concepts. Software modules will be implemented which allow easy replacement of key algorithms so that their performance can be readily evaluated experimentally on the service platform developed by our group in earlier projects.

The major focus and goal of the project was to develop algorithms for media understanding. Video retrieval was used as a generic application including analysis of still and moving images, speech, audio, and text. To make a decision whether a video is included in the results set of a query, the contents of the video must be analysed in order to compare them with user-set search criteria. The criteria can be given, in a general case, with any combination of the properties of the above modalities. The core methods are based on pattern recognition, knowledge-based analysis and digital signal processing of multimedia data. Simple demonstrations were implemented on a multimedia platform to show each operation and to test the usability of new services.

Vikings: timeline

MediaTeam Oulu's team for the Vikings Project included researchers specialising in digital signal processing, pattern recognition, knowledge-based systems and computer linguistics. The team emphasised cross-disciplinary research and included personnel from the domains of information technology, linguistics, and natural sciences. Two experienced linguists were employed, one specialising in language technology and one (postdoctoral) specialist in the prosodic analysis of speech. One postdoctoral and one doctoral member of staff in applied mathematics and numerical analysis strengthened the team significantly in Digital Signal Processing (DSP)-related tasks. Five research assistants at various levels of electrical engineering studies also worked on the project, specialising in various aspects of information technology. The project lasted three years, from June 2000 until May 2003, and had an overall budget of €420,000.

Tasks were distributed to student researchers in order to define topics for MSc or PhD works. Senior team members supervised younger ones. All engineering students were capable of writing software and developing algorithms. Linguists on the other hand worked in consultations with the team about the prosodic and linguistic properties of speech. Large technical meetings were arranged as needed, generally each month. Minor technical meetings were arranged each week within teams. The project steering group met three times each year. Although topics were agreed together, the two research groups (MediaTeam and VTT) worked relatively independently, however, some of the technological solutions were integrated for demonstration purposes, thus requiring close cooperation.

Vikings resulted in a number of different solutions and applications for content-based retrieval. A database system and a browser for DVD material were implemented allowing contents of DVDs to be organised in the database such that various data (video, sound, text) can be accessed from the browser. The browser user interface supports various methods of visualising metadata contents. Topic-based text analysis were studied in detail along with their potential applications for retrieving desired video shots by linguistic methods. Promising topical word categories were identified for different movie types and shot types. A data clustering tool was used for performing statistical analysis of topical word clusters. Promising results were achieved in classification experiments and a prototype was implemented for the visual browsing of script metadata.

The prosodic features of speech were a major area of study. Algorithm implementations (both selected from scientific literature and developed in house) were performed in the *Matlab* environment resulting in the identification and computation of 30 prosodic properties of a human voice. The study was based on three data sets which included speech samples of several people speaking in 5 – 7 different emotional states. Statistical data clustering was calculated by analysis of discriminant features and multi-dimensional scaling functions. Results show that a good separation of the emotional states of a human speaker can be achieved with statistical pattern recognition methods relying on multi-dimensional feature spaces and linear discriminant functions. Promising results were also achieved in the discrimination of the speakers themselves with these prosodic features.

A new sound profiling tool was developed that segments sound signals into speech, music, and mixed parts, and displays the results graphically. Statistical classification of sound using this method has very good performance. A simple browser was implemented which enables users to browse an audio database and retrieve sound profiles of recordings. Two new speech profiling tools were developed that identify 'turn-taking' positions in a discussion. This method can be used to recognise whether a recording includes discussions and to preprocess the discussion in order to analyse further the discussants' voices. Preliminary results were received from speaker segmentation/classification as well. Finally, a video image analysis system was developed in cooperation with **Maryland University**.[347] This software was entered into the international *VideoTREC* competition each year and was favourably placed with some useful feedback.[348]

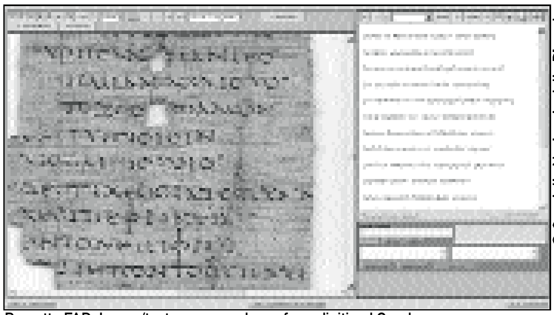
MediaTeam developed and implemented the database system, search engines, and browsers, with integration decisions being made routinely in the specification and implementation phases of the project. One of the key results was the advanced browsing method that enables effective exploration of the contents of video databases. The browser utilises content-based features in order to offer more relevant video shots to the user. The browser is thus a hybrid combining a query-based and browsing-based approach. We feel that this is a very effective method of search when one is dealing with complex multimedia databases. Other resulting products of the Vikings Project were around 40 scientific publications, three MSc degrees and one PhD. The project steering group evaluated the project routinely during its duration.

The project has encouraged further work in the field within MediaTeam. Currently, another research project is developing new feature fusion methods and algorithms for combining video, audio and text cues, a topic which is key to further success. The work has implications beyond simply the field of Information Retrieval. New kinds of terminal devices, high-speed wireless communications, real-time distributed applications, and intelligent media servers allow for more demanding mobile computing applications to be developed in the future. Communications infrastructures will change into hybrid networks in which mobile communicators, Internet, and digital TV services may be accessed through different types of terminals with specialist properties. The retrieval of digital video holds an important place in emerging multimedia services such as these. New

347 http://www.umd.edu/
348 For more information, see http://www.itl.nist.gov/iaui/894.02/projects/trecvid/

retrieval and infrastructure technologies will enable users of all types to make on-demand requests to media servers in order to retrieve digitised audio and video material for research. Data-mining applications could also utilise content-based IR technologies to retrieve material from extensive archives. Content-based technologies will become increasingly important with the growth in supply and demand of multimedia resources leading to an increasing development in this field.

Progetto FAD – Fondi e Archivi Digitali[349]



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Progetto FAD: Image/text correspondance for a digitised Greek papyrus

Progetto FAD (Digital Archives and Collections) began as a prototype system for the study and electronic publication of digital documents (both handwritten and printed). The idea was born at the Italian **Consiglio Nazionale delle Ricerche** (CNR), and the FAD project developed the system, including new Information Retrieval functionality. The proposal, introduced by the **Fondazione Primo Conti** of Fiesole,[350] involves three cultural institutes -- the **Gabinetto G.P Vieusseux** in Florence, the **Instituto Papirologico Girolamo Vitelli** in Florence, and the **Fondazione Rosselli** in Turin[351] -- as well as the *Istituto di Linguistica Computazionale* of the CNR in Pisa.[352] The scientific direction of the project was managed by Professor Andrea Bozzi, research director at the ILC. After a call for bids, the software development was carried out by **M.E.T.A s.r.l.**, Lucca, under the supervision of chief engineer Alberto Raggioli.[353] The project staff comprised a project manager, a technical coordinator, two senior developers and two junior developers. In designing and implementing the system, it was considered important to reconcile the largest possible dissemination with secure and robust protection of the information, two goals which are sometimes considered mutually exclusive.

FAD's primary aims and objectives were:

- To facilitate the digital conversion of different document types;
- To manage digital documents;
- To allow easy access to the documents over the Internet; and
- To convert the FAD archives automatically into a standardised format, compatible with the UNIMARC structure.

In short, the FAD system allows the searching for information from different catalogues, which have been realised with different systems. The project's functionality rollout

349 This case study is based on an email interview with Dr Andrea Bozzi, Senior Researcher on Computational Philology at the **Consiglio Nazionale delle Ricerche**, Pisa, Italy. The interview took place in June 2004. All other sources are given in footnotes. http://www.fadnet.org/
350 http://www.mega.it/primo.conti/contiho.htm
351 http://www.vieusseux.fi.it/; http://www.istitutovitelli.it/; http://www.fondazionerosselli.it/
352 http://www.vieusseux.fi.it/; http://www.istitutovitelli.it/; http://www.fondazionerosselli.it; http://www.ilc.cnr.it
353 http://www.meta-srl.com/

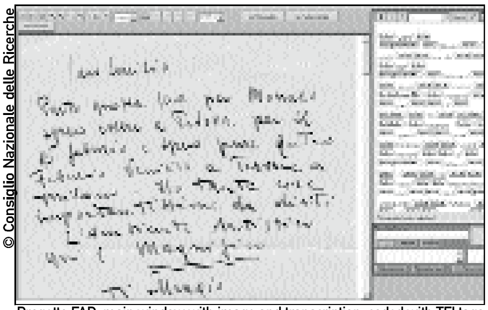
was split into two phases: the local and the global. The initial, local phase provided:

- Document-image storage with standard rights and digitization information in a homogenised electronic file, including the possibility of using a scanner for direct acquisition into the catalogue;
- Basic and advanced search options using standard metadata parameters such as author, title, or language, and with the option of customisable search criteria;
- Documents encoded in XML-TEI to increase exchange capability;
- A module to import different file formats; and
- Software which communicates updates to the users from the main server.

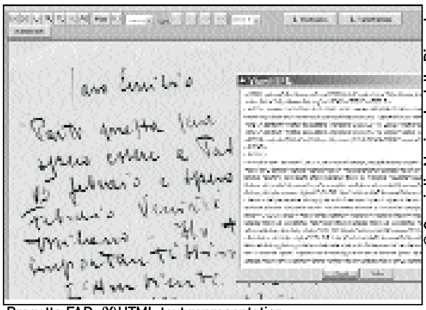
Following this, the main stage of the project focussed on Web presence ensuring the validity and security of files and services and increasing the institution's global visibility. Functionality included:

- Interfaces to search FAD documents, with all information concerning low resolution images, and the capability of delivering high resolution images locally within the rights restrictions of the documents;
- The functionality of integrating data from different servers and storage in a standardised way on the local file system.

Archives created by cultural institutions are imported into FAD databases which are structurally similar to those of the original systems but uniform (in the sense that the same relational database management system is used). FAD's procedures transform data as it is imported through the interface into the standardised format. This 'homogenised' catalogue is made available on the Internet, and acts to protect document copyrights by preventing their download.



Progetto FAD: main window with image and transcription, coded with TEI tags



Progetto FAD: (X)HTML text representation

FAD fulfils a series of functions, including some specialist Information Retrieval tasks: processing digital images to improve text recognition (in the case of printed documents) or text reading and interpretation (in the case of manuscripts). This is achieved by filters which allow users to zoom images and enhance brightness and contrast. These image manipulation techniques improve the results of transcription done with the use of a video-writing system.

FAD also includes a transcription component, an XML graphical editor developed by the project team which is based on extensions to **Microsoft**'s *Internet Explorer* browser. This allows the automatic insertion of some tags (for example, to mark up words and punctuation), as well as enabling manual mark up by users choosing tags from a window in the interface and adding values to the tag attributes using TEI tags defined by the user.

The system automatically produces correspondences between the words in the digital image and the words in the transcribed text. To achieve this, image processing techniques are used to locate parts of text within the image (in particular, lines of text). These techniques include segmentation algorithms, histograms and patterns distribution, and identification by means of neural networks. Once each line of text is located, statistical techniques are used for fixing the dimension of the word-box within the line on the basis of the word length in the transcription.

In terms of Information Retrieval, FAD relies on metadata (arranged into fields such as author, title, position, and subject) and on the elaboration of text contained within the digital images. Electronic text is produced by OCR tools for printed documents and manual transcription of manuscripts. The electronic text is automatically indexed using XML to define word tokens.

IR is naturally dependent on the way the documents are represented within the system. Textual mark-up conforms to current TEI standards and, since the texts are represented in XML, the base values of the tags can be used to provide a user with information and can thereby help with creating queries. Retrieval itself is performed on the inflected form. The selection of a form on the index represents a query to a database where all the cases in that form appear. The terms, in this case, are lemmatised by hand but the *Progetto FAD* team has developed a very powerful lemmatisation tool for Latin texts which will be linked to FAD in the near future.[354] The list of forms or lemmas is given and the user can choose from the list, one word at a time.

If the image has been segmented by words with a manual or automatic procedure, the system shows the area of the digital images where the selected word is situated. This is achieved by highlighting the word with a red box overlaid on the image, saving in advance the portion of text below in another image before replacing the highlighted image with the original.

In order to facilitate future use of automatic attribution of linguistic information,[355] a function exists within FAD which allows users to insert lemmas, abbreviations and other information manually in XML format. Retrieval of information from annotations, changes, and comments which have been attached to the digital texts and images is also possible. From a philological point of view, these inserted components will create a concrete critical framework for the collection. The project team hopes that this will promote the production of other cooperative electronic editions.

There were two main considerations for the technologies chosen to index the material. Obviously, the cost was very important and, because the relational databases support a wide integration of tools and technologies for resource management, automatic acquisition and indexing of XML documents was a great bonus. Use of the database for full-text materials was crucial. FAD now includes approximately 300,000 images which can be accessed by authorised users. The documents and books are on various subjects such as literature in Italy from the late 19th Century, the artistic and literary avant-garde during the beginning of the 20th Century, anti-fascism in Italy and throughout Europe, and objects and documentation concerning archaeological excavations in the Antinoe area of Egypt. FAD has had beneficial effects in terms of improving access to the material and promoting expertise. More specifically to the IR portion of the project, the project plans

354 More information can be found from the Cultural Heritage Language Technologies Web pages http://www.chlt.org/CHLT/demonstrations.html

355 For example, the use of a morphological or syntactical analysis tool to create lemmas.

in time to become Open Source and make the digital documents freely searchable on the Internet. At the moment it is only possible to search the collection by metadata, but in the future full-text searches will be possible. Transferring to Open Source technologies will initiate a re-write of the application into a non-proprietary language and eliminating dependence on the *Windows* platform components which are currently used.

Feedback following the project's results has been positive from libraries, but less so from archives. For the management of archival data, many aspects concerning the authority files and the links between a document and all those that have a relationship described by the archivist will still be taken into consideration. What makes FAD special is that, in comparison with multimedia commercial CD-ROMs, every user can decide upon his or her own personal way of interacting with the document without the need for a fixed path.

In the future, particular attention will be paid to the introduction of specialised modules for retrieving the linguistic content for those digital documents that are available not only in the form of images, but also texts. One example of future functionality is a powerful morphological analyser which will automatically lemmatise linguistic forms that are in works and documents in Italian or Latin. In this way, FAD will permit access to all the different media contexts (e.g. books, documents, or epistolary communications) in which a certain word-lemma appears from any of its morphologically derived forms. This feature will increase the linguistic and lexicographic studies possible to perform on the texts.

Progetto FAD was financed by the Italian **Ministry of Cultural Heritage and Activities**,[356] and had a total budget of €475,000. The project ran from January 2002 until June 2004 and was officially launched on May 14th 2004 at the **Teatro del Rondò di Bacco** in Florence.

Scenarios

Teaching effective Information Retrieval at a community centre

The ability to discover information on the Web is an important and versatile skill that many people take for granted. However, the vast majority of people have had no formal training in the effective use of search engines and often struggle to find the information they require.

A community centre provides Web access to its users via three workstations, but staff members notice a general lack of knowledge on how to search the Web. Helpers at the centre are often asked for information on local cultural events and heritage sites, but often do not have the skills themselves to help users locate this information online or answer technical queries posed by users.

The centre manager contacts a member of staff at a local university that teaches basic IR techniques and refers her to a pair of students currently studying this area. Through discussion with staff and helpers at the centre, the two students design a short series of workshops on the best use of Internet search engines and other IR facilities. They research how various search engines retrieve and rank results and the different searching methods which they support. Many of the local cultural and scientific heritage attractions

356 http://www.beniculturali.it/

provide 'in-site' searches on their Web pages, powered by **Google**, so the students concentrate on how to maximise efficient searching in that search engine. Discussion with centre helpers confirms that browsing is a common activity therefore the students include in their workshops tips on Yahoo! Categories, and how to get the most out of them.

The students are then employed to run the guided workshops for small groups at the community centre. Centre staff participates in the workshops as well as members of the public, and the staff produces laminated 'hints and tips' worksheets to be displayed around the workstations. By collaborating with the local library, which has a Web site of its own, the community centre puts the worksheets online with clear links from the library's homepage. The workshops are well attended and the students are persuaded to return after their end of year exams to repeat the sequence, once at the community centre and once at the library. The community centre initiates regular activity in guiding users through the worksheets, and offers a Certificate of Digital Literacy to users who can demonstrate effective searching skills. The users begin bookmarking favourite Web sites and are encouraged to share them with the wider community via a feature on the library's homepage.

Music recognition with a pattern-matching algorithm

A large regional library devotes one floor to an extensive collection of sheet music and audio recordings. Most of the music is classical, but there are also extensive collections of folk music and popular songs which have now passed into the public domain. Staff is inundated with requests to find tunes and songs. More than half of staff time is spent helping users identify the names and authors of music before they can search for the item in the library's online catalogue. Identifying tunes by these means is extremely unreliable as it relies upon the knowledge (and spare time) of the librarian present, resulting in some users never finding what they are looking for and leaving unsatisfied.

Commercial services which can identify melodies have become popular in recent years,[357] and staff at the library has the idea that a similar model could be extremely useful in the identification of those pieces of music whose titles and composers are not known. After investigating possible solutions, the Head Music Librarian requests funding to provide users with a version of the commercial model, adapted to fit the library's needs, in which an audio analysis application allows melodies to be transformed into text-based notation, stored in a database and searched very quickly.

After being allocated a budget, the librarian identifies an Application Service Provider (ASP)[358] that maintains a catalogue of music and the software required to search it. The application offered is very similar to that of the commercial company. Each tune is initially captured from an audio player device, converted to a plain text language describing the melody (irrespective of exact pitch and key) and stored within a database with metadata such as the title, author and year of publication or release. To identify a tune, the software captures a section of audio from an input device, converts it into the plain text format and runs a comparison on the catalogue.

As many of the tunes in the catalogue are contemporary, the library employs temporary staff to transform the more eclectic items in the collection (currently not included

357 For a real-life example see Shazam http://www.shazam.com
358 The Application Service Model is covered in Chapter 1 of DigiCULT *Technology Watch Report 2*, available from http://www.digicult.info/pages/techwatch.php

in the ASP's database) into the plain text notation, using tutorials supplied by the ASP, which are then added to the database. The library also sets up a very simple database using the unique object keys returned by the ASP application to match it to the library's catalogue number for an item and the level on which it is stored.

As renting the application from the ASP is significantly cheaper than buying or developing a solution, the Head Librarian can devote more funds to increasing the ways in which the new audio database can be used. He conducts a short study of the wants and needs of people searching the music library and, with the help of the library's audiovisual technician, designs an audio suite. This consists of a small soundproof room within the music collection which houses a computer, microphone and audio players. The music recognition software is installed on the new workstation. Users can whistle, sing or hum a tune or play a track into the microphone from CD, vinyl, magnetic tape, Digital Audio Tape, or MiniDisc. The software analyses the resulting sound file and converts it into text notation. Users can then search the entire database or refine their search using options such as genre, author/composer or date. When the results are returned, they are marked to show whether the music is within the public domain thereby, perhaps, giving the user more permissions. These results are automatically identified with the catalogue number so that the user can, with a single click, discover the item's metadata, permissions and whether it is held by the library.

The new music identification suite is extremely popular with library users and staff finds that it expands the role of the music library. Users not only have a much higher chance of finding the music they are looking for within the library but also begin using the application to identify music they know will not be held, such as recently published tunes and songs. After a relatively short space of time as this new function becomes better known, staff notices subtle changes in the makeup of Music Library users – and many users, attracted by the new possibilities on offer go on to discover and utilise more traditional library tasks and solutions.

Since the external database is maintained by the ASP, the librarians are not worried about it getting out of date and plan to renew their contract for the foreseeable future. The success of the system spurs the library into making plans to digitise all out of copyright audio recordings held within the collection as a precursor to providing their music recognition service over the Internet.[359]

Linking film archives

Two European Digital Film Archives have been collaborating for several years as their collections are highly complementary and provide interesting comparisons to audiovisual coverage of significant historical events. Both archives hold a large number of films by (and documentaries about) one filmmaker in particular, who lived in both countries at different points in his life. They have worked together on several special exhibits in both countries, providing copies of material for museums and referring interested parties to the other archive where appropriate. Both archives enjoy these collaborations and the added interest it brings to the archival holdings. They wish to encourage a crossover of interest, not only between other institutions in their home countries, but across international borders.

359 The possibilities, technological difficulties, and issues presented in this scenario are considered in DOWNIE, J. (2003) "Music Information Retrieval" in *Annual Review of Information Science and Technology* vol.37.

After meeting at an international conference, the head archivists discuss the possibility of virtually joining their collections – allowing users to search both collections from one online interface. The archivists are very excited about this idea and consider the great advantages that interoperability between their catalogues will bring. Unfortunately, the metadata for each catalogue conform to different models and (as well as the fact that metadata are in different languages) there are several obstacles to an easy and intuitive way of searching both catalogues.

The head archivists arrange a meeting at one of the archives and begin to identify problems and questions which need to be addressed before deciding if merging the catalogues is feasible. The archivists come up with the following list of issues:

- The catalogues consist of heterogeneous datasets – Should one or both sets be transformed? How can the metadata be transformed from one to the other without loss of data? Should both be transformed? The archivists appreciate that this would be a mammoth task given the amount of data involved.
- How can one search be effective on both schemata if the metadata are not transformed? The issue of interoperability is crucial to the success of this collaboration.
- A trans-lingual search would be relatively easy to implement by means of matched pairs of words in controlled vocabularies, but will the paired sets of words cover every eventuality? Will there be subtle differences in the ways the controlled vocabularies have been used? Are the controlled vocabularies at a similar level of granularity? This is a likely problem area.
- How can metadata crosswalks be created to solve some of these problems? Is there enough in common between the systems to make a crosswalk possible? If so, how best can the similarities and equivalencies be identified? How should idiosyncrasies be addressed?
- How will changes in the collections affect a common search tool? The crossover system must be robust enough to handle dynamic collection data.
- Will the search interface change? Should one interface be adopted over the other, or is a new interface required?

The archivists research current methods for solving some of these problems. They are happy to discover that frameworks already exist for accessing different datasets from a common interface[360] and that diverse collections can be united with a common schema such as the UK's Arts and Humanities Data Service's Common Metadata Framework (CMF).[361] They begin to identify common elements between the metadata schemata in order to begin working on a crosswalk and they identify elements which are unique to each institution. By careful comparison, the archivists can best approach a technological solution which will deal with the overlap as well as the legacy data

Both head archivists and their staffs agree that, rather than producing a bespoke metadata system to deal with merely their two archives, they must focus on a solution which will ease interoperability well into the future. For this reason, they fix upon the Open Archives

360 One example is SDSC's Storage Resource Broker (SRB), client-server middleware that provides one uniform interface for connecting to heterogeneous data resources over a network. SRB, in conjunction with the Metadata Catalog (MCAT), provides a way to access datasets and resources based on attributes or logical names rather than actual names or physical locations. More information is available from http://www.npaci.edu/dice/srb/

361 See http://www.ahds.ac.uk for more information.

Initiative's Protocol for Metadata Harvesting (OAI-PMH) as the best solution. OAI's mission is to promote interoperability standards for the efficient dissemination of content and its technological framework and standards are not dependent on any particular type of content.

The two film archives jointly fund a new staff position for a fixed term to facilitate the transfer of their schemata into a common system and begin contacting other film archives and institutions across Europe to investigate the possibility of including even more data in the unified search.

Using content-based retrieval for images of a sculpture park

A rural town runs a two-month-long arts festival every year, funded by government grants and voluntary contributions. One of the most celebrated and high profile features is the outdoor Sculpture Park where, each year, different sculptors display their work. Many of these artists are internationally renowned.

For several years now, the organisers have been asking visitors who own digital cameras to take pictures and bring them back to the box office in order to build up a collection of images of the sculptures from different viewpoints, in different weather conditions and as the natural surroundings change over the summer. The visitors' images are downloaded onto computers and burned onto DVDs to be sold as souvenirs at the following year's festival. The organisers would like to increase awareness of the festival and the number of visitors it attracts by adding these images as a searchable resource to the festival Web site.

Thousands of images have been recorded and stored over the past few years. Neither the public that submits the images nor the volunteer workers at the sculpture park have archival training and the metadata attached to the images is, at best, minimal. There is a high turnover of volunteers from one year to the next, making it almost impossible for new volunteers to mark up images taken at previous years' festivals. Additionally, the voluntary workers only work during the weeks of the festival and when staff members are working they are far too busy with other tasks to begin the slow process of marking up the images. As a result, the swiftly growing collection of images is never properly annotated with appropriate metadata.

One of the main organisers puts together a proposal outlining the problems to the rest of the team. She explains the concept of content-based image retrieval which, by this time, produces excellent results for collections with a relatively small number of different subjects. The organisers, keen to solve the problem, put together a funding bid, with matched funding from a regional company specialising in IR image searches based on content. The organisers and the company agree that all the images will be added to a database to be searched by content.

They realise that the sculptures are unique and fairly distinctive and the approach recommended by the company is to allow users to query the collection using comparisons of colour histograms and shape analysis. The company demonstrates an existing IR solution with which users can select colours from a palette and set the proportions of each colour within the image to retrieve images containing the same colours. Users can also specify basic shapes within a frame, filled with a chosen colour which is compared with image representatives using simple shape analysis techniques.[362] For example, if a user remembers that a sculpture was displayed on a grassy field, a green area at the bottom of

362 For a real world example of this, try out the QBIC layout search at The State Hermitage Museum Web site: http://www.hermitagemuseum.org/fcgi-bin/db2www/qbicLayout.mac/qbic?selLang=English

the frame will help to narrow down the results set. In addition to this functionality, the company can provide a "search by example" facility whereby, once an image of a particular sculpture is retrieved, more complex analysis is possible using its image content to find others like it.

The festival organisers, with a little help from their volunteers, identify a couple of examples of each sculpture and provide a little information on the year of display, the title of the piece and the sculptor. A programmer from the company designs a very simple Web interface allowing users to choose from four options: search using textual annotations, search by colour proportions, search by colour and basic shape, and search by example. The search using text metadata is performed on the greatly reduced set of images which were marked up with title, sculptor, and year. This returns two or three images, and the user can select his preferred image and run a similarity query on the entire collection. The dual approach allows users who can remember titles or sculptors to speed up the process of discovering images whilst not excluding those users who do not have textual information.

Once implemented, this resource is extremely popular and generates interest, not only from people who had already heard of the festival, but from all over the world, leading to an increased interest in the sculpture park and the rest of the festival. The innovative solution to granting increased access also impresses the governmental organisation which funds the festival and indicates possible further funding of innovative solutions in the future.

The Pros and Cons of IR Technologies

Introduction

Information Retrieval technologies have become an indispensable part of the large collections of electronic resources now available on the Web and elsewhere. In a situation where information discovery by browsing is not feasible, IR technologies are not so much a choice as a necessity. The generic advantage of IR is, of course, quick access to unsorted information. Although it is difficult to imagine any disadvantages to using a well-conceived and implemented IR system, there are risks and potential pitfalls which could inhibit the effectiveness of the technology.[363]

Advantages and Benefits

Immediate random access – Put simply, IR systems allow users to find information which they would not otherwise have found for a number of reasons: the set may be too large, the information may be in an unfamiliar language or lack a textual index.

Applicable to many kinds of information – Complemented by language tech-

363 Many of these risks are related to the area of indexing and representing the information. More details on issues surrounding representation can be found in AGOSTI, M. *et al.* (1991) "Issues of data modelling in information retrieval" available online at http://cajun.cs.nott.ac.uk/compsci/epo/papers/volume4/issue4/ep054ma.pdf, and in the "Digital Asset Management Systems" and "The XML Family of Technologies" chapters of previous DigiCULT *Technology Watch Reports* at http://www.digicult.info/pages/techwatch.php.

nologies and visual and aural analysis, IR systems can retrieve information from both structured and unstructured resources.

Access without indexing – Although not yet fully mature nor appropriate in all circumstances, technologies now exist which can access both textual and non-textual information without the need for manual indexing.

Subtle identification of information – Extraction technologies complement retrieval technologies by allowing researchers to make informed decisions on the relevance of documents and objects. Although it is no substitute for human comprehension, the retrieval of information from within objects can save researchers a great deal of time.

Minimises duplication of effort – IR can be applied to a number of different resources, allowing users to gain results from a variety of sources from one search.

Disadvantages and risks

Overwhelming scale of the task – An IR system is most necessary and helpful for searching a very large resource. In addition to the huge amount of time and effort which can be undertaken digitising an analogue collection and/or indexing its content, the sheer scale of a large information set can cause retrieval problems.

Different standards – Although differing methods of indexing are not intrinsically disadvantageous for the retrieval technologies themselves, they can affect the value of retrieval systems. Very few algorithms can effectively handle information which has been marked up according to a variety of rules.

Assumption of completeness – It is easy to forget that the recall of an IR system rarely hits 100%. Users who have exhausted the retrieved results will not generally continue their information search within a collection. As a result, at least some potentially relevant results are missed.

Loss of serendipitous discovery – A common factor in information discovery is simple luck. IR systems tend to preclude the more time-consuming random 'sifting' through, or browsing of, resources.[364] Innovative connections between ideas are often made by researchers browsing library shelves but this is difficult to model in the digital age.

Dependence on the skill of the user – Information retrieval can only ever be as good as the query provided by the user. A system can show a marked difference in efficiency between searches for skilled and novice information seekers.

Quickly evolving field – A state-of-the-art content-based retrieval system may be superseded by better technology in a relatively short space of time.

5. Introducing the Technology

Selecting a Specification and Development Environment

Before introducing an IR system it is important to consider various issues in order to ensure the best possible results from the finished system. Before undertaking the development or selection of an IR system, it is absolutely critical to have a thorough understanding of:

364 See *DigiCULT Thematic Issue 6*: http://www.digicult.info/pages/Themiss.php

- The content of an information set and any idiosyncrasies it may have;
- The likely needs and requirements of users;
- Their likely skill and familiarity with IR systems;
- The intended purpose of the IR technologies within the information discovery system.

Decisions on particular retrieval technologies will rely on the style and structures of any indices or object representatives produced. It is crucial that designers and developers adopt a holistic approach. There are enough important considerations on the matter of representation of the content of a collection to fill a book; suffice to say that an institution wishing to implement an IR system must consider these areas together.

Retrieval of the information by users

A good working knowledge of the current state of IR technologies will be helpful to any organisation selecting an appropriate system and particularly important when considering a bespoke system.[365] **IR-Ware** presents a categorised list of different IR software packages, including technologies aimed specifically at visual and audio retrieval.[366]

Some questions to consider:

- What are the basic functions which the system must perform?
- Is there an existing system which matches the needs of both the organisation and the material?
- Will the system search for discrete objects and return the entire object to the user, or will information be extracted or abstracted from within the documents?
- What are the potential file formats which the system must handle? How will each be approached?
- How large is the information set?
- Will the IR tasks be performed online? Is there a way to utilise existing online IR technologies?
- What searching strategy is most appropriate? The skills and needs of the users must be considered as well as the characteristics of the information set in order to achieve the best results.

Technological Infrastructure Issues

IR systems can be highly complex and may have significant technical implications both for the organisation of the material itself and the institution. It could be relatively simple to set up a single Digital Asset Management System on a collection which is already indexed. More comprehensive and versatile retrieval system will require significant research, investment and development. It is likely that a large networked system will require dedicated hardware and a server.

365 A selection of white papers, trial software, and Web casts can be accessed from the Networked Computing Tech Library at http://techlibrary.networkcomputing.com/rlist/term/Information-Retrieval-Software.html

366 http://www.ir-ware.biz/. Readers are also encourage to refer to the Open Directory category at http://dmoz.org/Computers/Software/Information_Retrieval/

The process of introducing the technology is likely to take the following form:

1. Comprehensive needs analysis to answer the preparatory questions (above);
2. Research of current technologies and study of their use in other similar organisations;
3. (Cataloguing, indexing or representing the information set if necessary);
4. Selection, adaptation or development of a system, including the acquisition of related technologies (e.g. a speech recognition system), where necessary;
5. Thorough testing with appropriate data and work loads;
6. Refinement of the retrieval algorithms;
7. Installation of hardware and software, load testing (for networked applications);
8. Deployment (preferably including features for ongoing evaluation and refinement).

Staff and Policy Issues

Collaboration between those with an in-depth knowledge of the materials and those with technical knowledge about the way in which IR works is necessary to define and select the best solution. It is likely that organisations will need to bring in external expertise from IR technology specialists. IR solutions are likely to be large and take a long time to implement, therefore it is crucial that activity is managed to ensure a consistent approach to the various aspects of the project.

Many heritage institutions will already have some sort of IR system, so a discussion of the benefits of a more innovative approach will be beneficial. Curators of digital information will generally be excited about the new modes of access and dissemination of their information made possible by the latest retrieval technologies. It is important to emphasise the timescale involved and the need for thorough testing before the system goes live.

Location-Based Systems

Executive Summary

This chapter follows on from DigiCULT's discussion of *Mobile Access to Cultural Information in Technology Watch Report 2* (p. 91-118), exploring technologies such as GPS (the Global Positioning System) and GIS (geographic information systems) in greater depth.

A GIS enables the visualisation of the geographic aspects of a body of data, stored in one or more searchable databases. Input is usually provided in the form of digitised maps which the system translates into geographic data. When the system is queried, the GIS turns user input (whether in the form of a street address, a postcode, or grid co-ordinates) into an explicit map location, with which the user can interact. This process is known as *geocoding*. Geographic data can be stored as vector graphics (where linear data are stored as strings of x and y co-ordinates) or as raster graphics, which express data at pixel level as a set of grid cells. The raster model is better for portraying subtle and gradual changes while vector graphics are better for linear data. Most GISs use both kinds of representation, gathered from multiple sources. They can then analyse, manipulate and present this data in a variety of ways for different purposes.

GISs are used in a wide range of sectors, from the emergency services, to environmental agencies and industries like mining, exploration, etc., indeed, wherever spatial data analysis has a part to play. The best-known examples of GISs on the Web are mapping services like **Maporama**, **Streetmap.co.uk**, and **Yahoo! Maps**.

The GPS consists of twenty-four satellites (owned by the US **Department of Defense**) that allow ground receivers to ascertain their spatial location. Each satellite continually broadcasts its changing position and time. GPS receivers triangulate their own position by taking bearings from three of the four visible satellites. The result is provided in the form of a geographic position – latitude and longitude – which can be accurate to around one metre.[367] The fourth satellite establishes the user's altitude. When the data are linked with dynamic mapping capabilities the location can be output visually in map form.

For some time, scientists have used GPS data to measure phenomena like the movement of polar ice sheets and the Earth's tectonic plates. Since US President Bill Clinton withdrew GPS Selective Availability in May 2000, accurate GPS has been affordable for most people for personal use. In addition to outdoor use in pursuits such as hiking, skiing, flying, and sailing, GPS receivers can be used in cars to give drivers their current locations.[368]

In the cultural heritage sector, location-based systems could be used very simply on institutions' Web sites to direct visitors. More in-depth applications of the technology will include archaeology, particularly when GPS/GIS

367 http://www.starlinkdgps.com/dgpsexp.htm

368 The EU is currently working on an alternative to GPS, known as *Galileo*. The first satellites for this new system are due to be launched in 2007. http://europa.eu.int/comm/dgs/energy_transport/galileo/index_en.htm The **Dashwerks** *DashPC Telematics Server* is one such system employing GPS for convenient in-car navigation. http://www.dashpc.com/

are used in conjunction with virtual or augmented reality applications. The **National Monuments Record of Scotland** (NMRS) provides a good, large-scale example of how GIS can be used in the cultural heritage sector. The NMRS maintains a GIS database which holds site details together with location and bibliographic details. One of the original sources of information for the database was taken from the **Ordnance Survey** (OS) Archaeological Division. This has since been greatly enhanced with information from the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and external survey projects. A project to incorporate all architectural records has been operating since 1996. It is anticipated that there will be about 250,000 site records in total when the architecture upgrade project completes and an index to over 1,000,000 collection items. In 1998, the NMRS database was launched on the Internet as *Canmore* (Computer Application for National MOnument Record Enquiries).

Case studies on the *ODIN Mobile* and *CHIMER* projects show how location-based systems can be fruitfully combined with mobile and static devices to provide "anytime, anywhere" access to cultural resources, and to help users interact and integrate more fully with the objects, building and people around them.

Introduction to Location-Based Systems

Background

Location-Based Systems (LBS) take a user's current position into account for the purpose of providing a *service*, powered by the ability to determine or discover the geographical location of a mobile device and subsequently provide services based on this information.[369] User location information is usually expressed in X-Y-Z coordinates, produced by a Location Determination Technology (LDT).

The world's best-known positioning system is the *Global Positioning System* (GPS). This consists of twenty-four satellites launched between 1978 and 1994, orbiting the Earth and allowing users with dedicated receivers to ascertain their geographic location. GPS position determination is based on measuring the distance to three of the four visible satellites thus determining the three basic coordinates of each user's position: latitude, longitude, and altitude. Originally developed by the US Department of Defence to meet military requirements, GPS has since been adopted for civil applications, in particular travel advice. The first indoor location-based application was the *Active Badge*, developed by **Olivetti Research Ltd** between 1989 and 1992.[370] The Active Badge's in-built tag generates an infrared signal four times per minute. These signals are picked up by a system of sensors located around the building. A control unit, which is also part of the network, polls the beacons, processes the acquired data, and displays the results in an appropriate visual form.

PARCTab was the first location-based application to be deployed for mobile devices, designed and prototyped in 1992 by **Xerox**, **PARC** as part of its work on ubiquitous computing.[371] The system is intended for indoor location determination and consists of palmtop

369 This definition shows that the ability to determine a geographical position is generally considered a means for providing mobile users with *services*. It may be preferable to use the term 'location-based services' instead of 'location based systems,' although the terms can be used interchangeably, and are abbreviated as LBS. See also http://www.gisdevelopment.net/technology/lbs/techlbs003.htm

370 http://www.cs.colorado.edu/~rhan/CSCI_7143_002_Fall_2001/ Papers/Want92_ActiveBadge.pdf

371 http://seattleweb.intel-research.net/people/ schilit/parctab-pcs-jan96.pdf

computers that can exchange wireless data with workstation-based applications via infrared transceivers.

The first distinctively location-based services were provided by mobile telecommunications network operators. The requirements of the **US Federal Communications Commission** have insisted since 2001 that network operators are able to provide a caller's location and phone number (the so called E-911 directive) to emergency services when necessary.[372] With recent developments in the field of communications, geospatial positioning systems and geographical information systems, location-based systems are becoming increasingly important for the mobile world. In the near future they will benefit both users and service providers almost ubiquitously.

Services and Uses

Location-tracking services

Location-tracking services usually use GPS receivers as positioning components, employing an Internet-enabled cellphone or a personal digital assistant (PDA) as communication components for visualising the tracking service. No information needs to be sent to the mobile object. Examples of location-tracking services include vehicles and goods, people (children, adults with health problems, people in hazardous environments or dangerous terrain), livestock and pets, and *GeoFencing*. The last of these refers to systems which generate alerts when tracked objects enter or leave a predetermined area. This can be used to monitor prisoners on parole, for example, or control the movements of livestock.

Position-aware services

Position-aware services necessitate a two-way communication between service provider and user device. Such services have a variety of current and potential uses. In *traffic coordination and management*, these services provide information on traffic flow, route advice, and weather conditions, as well as practical information such as toll prices for the use of motorways or bridges. In *eCommerce* they provide location-aware advertising and content delivering as well as shopping assistance. In *integrated tourist services*, information can be provided on accommodation, transportation, cultural events, guided tours, and prices.[373] In *education*, resources can be shared between users in a room, school, or even across larger distances.

The Location-Based Market

The ongoing boom in LBS implementation has attracted the interest of many new players, developing and offering new and improved location-based services. According to **Ovum**, the LBS market in Western Europe is expected to reach €5.37 billion by 2006, with approximately 44% of mobile users employing some kind of LBS.[374] This is still only a

372 http://www.fcc.gov/911/enhanced/
373 See for example *M-Guide*, which provides location-based information services for Athens, Greece and Turku, Finland. http://www.exodus.gr/m-guide/
374 http://www.northstream.se/objPage.asp?objID=195&objTypeID=2

small share (around 1%) of the total operators' earning estimates for the same year. Another survey from **Datamonitor** suggests that the revenues earned providing mobile content (data sent over mobile phones to users) should reach more than €25.6 billion in 2005, compared with €1.95 billion in 2001. **Datamonitor** sees location-based services generating only €2.0 billion of these revenues by 2005 due to the lack of standards in the still-maturing technology.[375]

According to **ABI Research** (April 2004), the total revenue garnered from LBS may exceed €2.93 billion by the end of the decade.[376] The largest share of this will be from company services such as employee and asset tracking. Navigation, weather services and child tracking are among the other location-based services likely to be most readily embraced by consumers. **Strategy Analytics**[377] (January 2001) claims that by 2005 the market for location-based services will reach €5.3 billion in the U.S. and €7.32 billion in Europe. A small part of that revenue will come from tracking services while position aware services will be predominant.

Whether LBS will reach these figures in these time scales depends on a number of factors such as standardisation, consumer acceptance, quality of positioning technology, level of accuracy and security issues. Geospatial technology expert Yaser Bishr predicts that by 2006 telecommunications companies and other mobile service providers will acquire the majority of GIS vendors and assimilate their technologies into wireless Web service infrastructures.[378]

Privacy issues

Information privacy means a right to fair processing, the right to private communication, the right of authentication and the right of anonymity. There is no current legislation which deals unambiguously with privacy issues in location services. The identification of potential problems related to user privacy will be of vital importance for the success of LBS. Service providers constantly strive to guarantee consumer confidence and LBS can only truly thrive when users feel totally comfortable with location privacy guarantees. In some cases, they may even be ready to make compromises to their personal rights if the service is judged to be worth it.

Standardisation

Many institutions are currently working on standardising LBS, on both the network and application sides. Key players in these efforts are the **3G Partnership Program** (3GPP) and the Location Interoperability Forum (LIF), which work on the addition of LBS capabilities to future 3G networks and on the development and implementation of network- and technology-independent solutions.[379] There is no doubt that the result of these efforts will have a huge impact on the success of LBS, affecting the choice of technology, the investment required to start or upgrade existing services, not to mention the effects on their accessibility, ease of use, and cost. This is a similar situation to that relating to geographic data, where

375 http://news.bbc.co.uk/1/hi/business/1168362.stm
376 http://www.eurocomms.co.uk/news/story.shtml?news.REF=1041
377 http://www.mbizcentral.com/magazine/story/archive/january-2001/guide-to-loc-A
378 http://www.jlocationservices.com/LBSArticles/Bishr.Positioning%20Position%20Technology_article.pdf
379 http://www.3gpp.org/; http://www.openmobilealliance.org/tech/affiliates/lif/lifindex.html

existing formats have to be standardised for inter-module communication in an LBS. This encompasses standardisation of both metadata and the geographic data itself. The **ISO** *TC 211* and the UK **Office of Government Commerce** (OGC) frameworks provide a solid background for further developments in the field, based on XML and W3C recommendations.[380]

Location-based systems cover a broad range of technologies and, in order to allow interoperability between their components, the need for standardisation is obvious. Such components include content and applications, network equipment, communication equipment, service provision, and end-user devices. The flawless integration of these components in reliable LBS will demand Open standards for data exchange and application interfaces. With Open standards evolving in both GIS and Wireless technologies, the possibility for comparable and compatible standards in Location Based services is fast becoming a reality.

How Location-Based Systems Work

Principles and Categories of Location-Based Systems

There are two main types of location-based services: *location-tracking services* and *position-aware services*. The former rely on the tracking of mobile objects by other parties (service providers) and are limited to tracking applications where no information is sent to the objects.[381] The latter type relies on the device's knowledge of its own location.[382]

A typical location-based system is likely to consist of five components: (i) a positioning device, used to measure the position co-ordinates of the mobile device; (ii) a communication component, ensuring one- or two-way communication between the mobile device and the service provider; (iii) a geographic information component; (iv) a location management component, usually a remote server which performs further processing of positioning and geographic data; and (v) a service component, i.e. data provided to the mobile user or device.

The positioning element is used to measure the position co-ordinates of the mobile object or device. This is often a dedicated GPS receiver, but standard cellphones can be used to good effect where high degrees of accuracy are not essential. The communication element provides one- or two-way communication between the mobile object and the service provider. This link is used to transmit the location co-ordinates to the service provider, and the service to the mobile user. Cellphones combine positioning and communication capabilities. All other positioning devices use separate communication components, typically network-based. Location-based systems can be categorised according to the type of network used. Cellphone networks are currently the preferred way to transmit location co-ordinates. WLAN network-based methods transfer position co-ordinates to the service provider via an *Ethernet* (802.11), *Bluetooth*, or *WiFi* (Wireless Fidelity or 802.11b) interface.

Other solutions include *Internet* (*TCP/IP*)*-based* deployments, and *networked applications* whereby all positioning components are connected directly to a networked information management system (IMS). Such communication tools are used by most indoor location

380 http://www.isotc211.org/; http://www.ogc.gov.uk/
381 http://www.intel-research.net/Publications/Berkeley/072920031046_154.pdf
382 *Ibid.*

techniques: infrared, ultrasonic, RFID, real time location and Ultra-Wideband (UWB) systems.

The geographic information component refers to the physical environment where the service is to be delivered. These are tools which serve and manage maps of particular areas, of streets and blocks, of natural elements (such as planes, lowlands, mountains, lakes and rivers, or simply points-of-interest such as supermarkets, entertainment areas or service stations), software tools to generate and use them, hardware to process and display them and finally the personnel to work them. GIS is a fundamental technology required by most LBS applications.

The location management component processes location coordinates in order to extract value and context from the geographic data. A Mobile Positioning Centre (MPC) may gather and manage positioning information, interfacing with applications that make use of it. It controls all procedures related to the authorisation, authentication, and billing of users, and deals with issues like privacy. The service element is the data returned to the mobile user upon request or a personalised position dependent service.

Geographic Information Systems (GIS)

What is GIS?

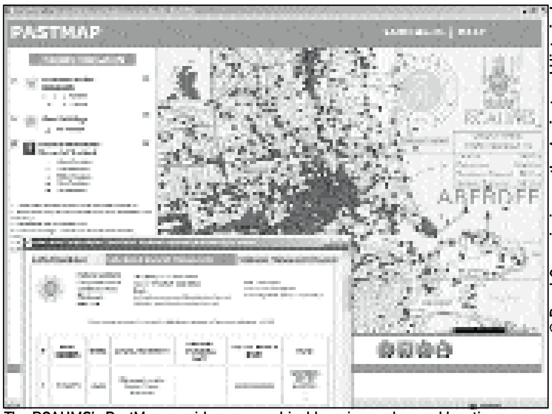
A geographic information system combines layers of information about a *place*.[383] Essentially it is a combination of computer hardware and software linking geographic data with descriptive information. GISs do not merely mimic the concept and functions of paper maps: in addition to geographic data they present layers of complementary information. The software and associated maps assist in providing the visual representation of the overall procedures contained within the information management system. But GIS is not primarily about displaying digital maps and depicting distributions of data. The essence of GIS lies in its power to analyse the data and supply additional information, making a GIS a complex computer system which stores and utilises data about objects on, above or underneath the surface of the earth, assisting in the analysis, management and visualisation of spatial and geographic data.[384] Geographic information systems are sometimes referred to as 'smart maps' linking the functionalities of databases and maps.[385]

The basic functions of a GIS system are:

- Geocoding, an automated process that links user data with map data, and in converse process *reverse geocoding*;
- Proximity search;
- Nearest neighbour search;
- Geodetic (relating to the measurement of the Earth's surface) conversion;
- Point-in-polygon operation (a GIS overlay procedure which determines whether the points of one dataset are contained within the polygons of another dataset);[386]

383 http://www.gis.com/whatisgis/
384 http://www.mda.org.uk/info23l.htm
385 A fine introduction to GIS (including examples) can be found at the *Ordnance Survey GIS Files*: http://www.ordnancesurvey.co.uk/oswebsite/gisfiles/
386 http://www.cartage.org.lb/en/themes/Reference/dictionary/dictcomputer/P/16.html

- Distance calculation;
- Multi-modal routing (calculation of optimised routes);
- Spatio-temporal dynamic calculations;
- Map rendering for mobile devices. [387]



The RCAHMS's PastMap provides geographical layering and record location

The main concept in the workings of GIS is that of *layering*. This combines mapping and data storage functions, allowing the creation, manipulation and analysis of spatial data. In order to do this, a GIS encompasses basic elements like hardware, software, rules and techniques for data management, procedures for deriving information and the expertise of qualified personnel.

The geographic data component refers to the physical environment where the service is to be delivered. In simple terms, this includes maps, software tools to generate and use them, hardware to process and display them and the personnel to operate them.

Where is it used?

The *Canada Geographic Information System* (CGIS) is one of the earliest examples of a GIS, created in the mid-1960s to analyse Canada's national land inventory and still in operation today. The CGIS elaborated a number of technical and conceptual issues that are relevant to contemporary systems. In 1964, Howard Fisher established the **Harvard Lab for Computer Graphics and Spatial Analysis** which soon became an important research centre where innovative software for spatial data handling was created. Two years later, Fisher developed *SYMAP* (the Synagraphic Mapping System),[388] the first real software system to facilitate computer mapmaking.

GIS systems are found in a wide range of applications, including Emergency Services (Ambulance, Fire and Police); Environmental Monitoring and Modelling; Business Site Location and Delivery Systems; Industrial Transportation and Communication; Energy – Mining and Pipelines; Healthcare; the Military; all levels of Government; and Education and Research. The British **Ordnance Survey** uses GIS for education, for adding real-world information to its regular maps and linking maps to other resources.[389]

Domain-specific uses to which GIS can be put include administration, network solutions, ecosystem management and environmental monitoring, oil spill and contamination monitoring, site location and client distance measurement, modelling of future trends, clusters and comparison of data (indeed anywhere that spatial data analysis is needed) and combining various display methods in a single system. In all such cases, GISs are used directly. In LBSs they are more or less essential for the operation of the application but the end user need not be aware that GIS is helping provide the data.

One of the most exciting new applications for GIS is across the Internet. The possibility

387 http://www.csiss.org/events/meetings/location-based/goodchild_lbs_final_report.pdf
388 http://www.geography.wisc.edu/sco/gis/history.html
389 See the OS's http://www.mapzone.co.uk for example.

of providing online services into people's homes uncovers new opportunities to all heritage institutions involved in improving public understanding, access to and enjoyment of world culture.[390]

How does it work?

A GIS stores information as a collection of thematic laye rs that can be linked by geographical coordinates. This simple but powerful concept has proven invaluable for solving many real-world problems. Simply put, GIS works by relating information about an object or event to a location. To do this successfully, a GIS utilises five essential components: data, hardware, software, people and methods. The last two of these will be covered in greater depth towards the end of this chapter, but it is worth taking a moment to outline the technical components here.

Data

In any GIS, each geographical feature is represented by geometric spatial data such as points, lines and areas, and non-spatial data such as names, statistics and classifications. There are two ways of inputting and visualising such data: *raster* and *vector* data models. The vector model describes discrete objects in terms of points, lines and areas, and uses point, line and area data types to define the locations and boundaries of referenced features. The vector model is sometimes also referred to as an object-based model. Satellite images and aerial photos are usually stored in this format.[391]

The raster model, on the other hand, partitions space into cells and records the contents of each cell. Cells are usually square, rectangular or hexagonal in shape. Raster models consist of a set of thematically specific layers, each presented as a grid array. For a particular theme of interest, each cell records a single value which may be the category within a theme, or a numerical value, e.g. temperature. Raster data models are normally used to record less precisely surveyed data.

A GIS will often combine data from multiple sources. Possible sources include digitised/scanned *maps* (which may be purchased, donated, downloaded, or created by professionals), *databases*, accurate GPS *co-ordinates*, remote sensing and aerial *photography*. The last of these involves satellite imagery and overlapping aerial photographs created by photogrammetric instruments. Satellite images and aerial photographs are typical examples of remotely-sensed data.

GIS applications are generally aimed at deriving information from the data available in the geographical database. This is done using different techniques, such as *geoprocessing, analysis of remote sensing data*, and *image processing* techniques. Geoprocessing involves the derivation of information through the analysis of existing GIS data and includes such procedures as data conversion, geographic feature overlays, topology processing, coverage selection and analysis.[392] Commonly occurring types of spatial queries are those of measurement, proximity, contiguity, containment, coincidence and least-cost paths.

390 See Peter Ladstätter, 'GIS on the Internet: Applications, Technologies and Trends,' for a more in-depth account of Web-delivered GIS.
http://www.sicad.com/pages/about_us/publications/pdf/v9902_aw_ladstaetter.pdf
391 http://www.mda.org.uk/info23l.htm
392 http://www.csiss.org/cookbook/glossary.php

The analysis of remote sensing data allows different types of information to be derived and then combined with other spatial data within a GIS. This method is used to collect information on a subject without necessarily coming into contact with it.[393] In the case of GIS, this means data about the earth (usually in the form of images) provided by aerial photography, satellites, airborne scanners or cameras, and radar systems. Sensors mounted on satellites or aeroplanes are used to measure the energy reflected from the earth. The data obtained can be displayed onscreen as a digital image or printed as an analogue photograph.

Developed for different purposes, GIS and remote sensing both provide information about the earth's resources. Developments in computer technologies have made possible the integration of data from the two sources. Most GIS software packages permit remotely-sensed data to be imported (or at least displayed) within the software application. This allows users to overlay remote sensing data layers with other spatial data layers. Remotely-sensed images can be combined with GIS datasets to provide continuous views of particular areas, to extract GIS data layers (such as contours), and to build *footprints* (i.e. the total area where a specific transmission can be received.)

The data processing carried out in remote sensing is a form of image processing, since remotely sensed data usually take the form of digital images. It involves a series of steps. In the *pre-processing* stage, images are prepared to aid computer analysis in terms of digitisation, conversion into suitable formats, reconstruction, restoration and/or correction of radiometry and geometry parameters. To *transform* the information, image enhancement, spatial and geometric transformation and/or data compression techniques are normally required to generate a thematic map or database. The *classification* stage involves the categorisation (or labelling) of image features, using techniques such as statistical analysis, pattern and feature recognition, texture analysis, segmentation and matching. Finally, the image data are *output* either in analogue form such as film or colour copy or in the form of a digital database which usually makes up one of the layers of geographic data in the GIS.

Software and Hardware

GIS data alone are useless without the functions and tools needed to store, analyse and display geographic information. Key components of GIS software include tools for entering and manipulating geographic information, a database management system (DBMS) for storing and retrieving this information, and dedicated tools for creating intelligent and query able digital maps.

The computers and devices on which a GIS operates form its hardware component. In the past, GIS was always associated with expensive and hard-to-use UNIX workstations, but today GIS is often found on a wide range of user-friendly and affordable systems, including desktop PCs and personal notebooks. The typical GIS hardware setup consists of a computer, input devices (keyboard, mouse and scanner), output devices (monitor, printer and plotter), and storage devices (including hard drives, CD recorder and DVD RAM).

As with many types of software these days, introducing GIS to an organisation need not be expensive. The *Open Source GIS* project is an attempt to build a complete index of Open Source and Free Software GIS-related projects.[394] In August 2004 it linked to over 170 packages, ranging from simple calculators for measuring the distance between two postal zip codes regions to software for capturing and decoding information from weather satellites.

393 http://www.unesco.org/csi/pub/source/rs15.htm
394 http://www.opensourcegis.org/

Positioning technologies

Introduction

Location-based services can be grouped according to the positioning technology used to pinpoint the location of a mobile object. The fundamental element of a location-based system is its positioning component. These can be cellphones incorporating Subscriber Identity Module (SIM) cards, GPS receivers, inertial sensors (geometers), transceivers and tags (ultrasonic, infrared, radio-frequency, RFID, ultra wideband, magnetic field), or wireless LAN components such as palmtop computers, PDAs and laptops. Many of these technologies have been covered in DigiCULT work and our focus here will therefore be on those components which either have not been discussed or those for which location determination capabilities have not been important thus far.[395]

Cellphone positioning elements

Positioning technologies based on mobile phones fall into two main categories: *network-based and handset-based* (or network-/handset-centric) solutions. Network-based solutions do not depend on positioning resources built into a mobile phone or its SIM card, whereas handset-based solutions do. The term 'network-based' refers to a series of terrestrial base stations accumulating positioning information and sending data to a centralised server which then computes locations. This differs from the handset-based method where the handset performs the calculation itself.

Network-based positioning technologies

COO (Cell Of Origin) Technology

Cell of Origin (COO) is a mobile positioning technique for finding a caller's cell location.[396] COO is the only positioning technique that is widely used in wireless networks and is suitable both for the emergency services and commercial uses. To determine a position, the location of the base station is ascertained from the cellular transmitter and assumed to be the location of the caller. This technique is not precise. Depending on the number of stations in the area, the accuracy of positioning can be as close as one hundred meters in a city area, perhaps, or in the order of several kilometres where base stations are located more sparsely. When greater precision is required, the COO technique is often used in combination with other location technology. An example of this is the *Enhanced Cell-ID* network technology which combines standard COO techniques with other technologies, thus increasing the level of accuracy over basic Cell ID (typically between 75 and 500 meters). In GSM networks, COO can be combined with a Timing Advance (TA) technique (where handset range from the base station is measured) and/or Received Signal Level technique

395 See for example *DigiCULT Technology Watch Report 1*, "Smart Labels and Smart Tags" (pp. 63-93), and *DigiCULT Technology Watch Report 2I*, "Mobile Access to Cultural Information" (pp. 91-118.)
396 This technique is also known as Cell Global Identity (CGI). A cell is the basic geographical coverage element of a cellular phone system.

(where average signal strength is measured). In **UMTS**'s *Wideband Code Division Multiple Access* (W-CDMA) cellular networks, COO can be combined with Round-Trip-Time technique (the W-CDMA version of Timing Advance) to improve accuracy. Despite COO's lack of precision, it offers certain clear advantages: quick location determination (usually in the region of a couple of seconds), and easy deployment since no equipment or network upgrades are required.

TDOA (Time Difference Of Arrival) Technology

Another simple network-based method, TDOA uses the time differences for a signal to travel between the mobile device and three different base stations as an indirect way of location identification. Location measurement units mounted on each station compare the time differences, and taking into account the known propagation speed of the signal they calculate the distances to the mobile device, thus defining its exact position. To achieve accurate positioning, the clocks at the base stations must be precisely synchronised, usually done by GPS or atomic clock. This technology is sometimes referred as *Uplink Time Difference of Arrival*, where uplink means a radio communication from a mobile terminal to a base station.[397]

Characteristic features of this technology include the ability to determine locations accurately (typically 50m or better) in outdoor and indoor areas alike. As with COO, TDOA does not require upgrading of basic hardware or of the network. Along with *Advanced Observed Time Difference (E-OTD)*[398] (see below) and the *Assisted Global Positioning System (A-GPS)*,[399] (see *GPS* below) TDOA is one of three high-accuracy wireless location standards adopted by the **3GPP** (Third-Generation Partnership Project).[400]

TOA (Time Of Arrival) Technology

TOA is similar to TDOA but uses the absolute time of arrival of the signal at a certain base station rather than the difference between signal propagation times from the mobile terminal to base stations. Since signals travel with a known speed, the linear distance between a mobile device and base station can be calculated from the time of arrival using location measurement units (LMUs) installed at each base transceiver station. As with TDOA, synchronisation of the base stations is important to ensure accuracy in the location determination. This technology is sometimes referred as *Uplink Time of Arrival*. The cost of implementing this technique is high due to the large number of LMUs required, and is not proportional to the improvement in performance.

AOA (Angle Of Arrival) Technology

This technique requires a complex antenna set at each base station, operating together to

397 http://www.cs.berkeley.edu/~adj/cs294-1.f00/glossary.html

398 Enhanced Observed Time Difference. This method is based on measurements in the Mobile Station (MS) of the time difference of arrival of bursts from nearby pairs of base stations. It is employed to calculate the position of the MS and may be used for Location Service. (Source: http://www.mpirical.com/companion/Multi_Tech/E-ODT_-_Enhanced_Observed_Time_Difference.htm)

399 Assisted Global Positioning System: a technique enabling mobiles and cellular networks to establish accurate positioning information. The system utilises both the GPS and the terrestrial cellular network and is one of the Location Services methodologies. (Source: http://www.mpirical.com/companion/Multi_Tech/AGPS_-_Assisted_Global_Positioning_System.htm)

400 http://www.3gpp.org/ See also http://www.wirelessdevnet.com/news/2003/125/news9.html

determine the incident angle of an arriving signal. LMUs at different stations process this information in order to pinpoint the caller's location. AOA systems are designed to compensate for multipath signals, since these may compromise the location determination. The process of installing and aligning antenna arrays can be complex and costly. Hybrid methods have been developed which use the best of both AOA and TOA to provide improved positioning.

Radio Propagation Techniques (RF Fingerprinting)

This technique uses a predetermined mapping of radio frequency (RF) characteristics to provide an estimate of a mobile device's position. It is based on the comparison of the signal signature with a database that stores a physical model of the RF coverage area. LMUs correlate known RF characteristics (multipath signal attenuation, propagation and signal loss) with real-time information acquired through the mobile phone. This technique provides extremely accurate location tracking results (typically within a few meters) and rapid deployment at reduced expense. It is suitable for both urban and suburban areas and is particularly well suited for indoor deployments. RF Fingerprinting works with both 2G and 3G handsets, providing a solution for existing and future users as well as a potential complement to GPS-based applications.

Handset-based positioning technologies

SIM Toolkit

The SIM Toolkit allows communication between a SIM card and a location server application, either of which may contain additional algorithms to support mobile positioning. This is a good technique for obtaining position information while the mobile device is in an idle state. Positioning information may be as imprecise as that achieved through the COO method although additional procedures such as *timing advance* (TA) or *network measurement report* (NMR) can be applied to improve accuracy.

CGI + TA (Cell Global Identity) + Time Advance

This positioning technology relies on two parameters: *Cell Global Identity* (CGI) and *Timing Advance* (TA). TA is a technique which allows time frames from each mobile to be synchronised when received at a base station. It relates to a network-determined time difference of the actual arrival of a signal from a mobile phone and the allocated time. TA is measured when a communication is to be established between a handset and a particular cell. Simply stated, mobile phones must transmit their data some time ahead (according TA) to keep in synch with the cell base station. Thus the TA parameter is used to estimate the distance between them. The precision of a combined CGI+TA system is reasonable, usually offering an error margin of less than 10m.

CGI + NMR (Cell Global Identity+ Network Measurement Report)

This technique relies on standard measures of the field level performed by the handset, given that the SIM card is accordingly modified. The NMR method is based on signal power measurements (RF-patterns) which are part of the signalling for handover purposes.[401] A database holds these entries which describe a particular position. When the position of a mobile terminal is to be determined, snapshots of the RF-patterns are taken and compared to the database values.

E-OTD (Enhanced Observed Time Difference) Technology

The enhanced Observed Time Difference (E-OTD) technique relies on signal measurements performed both by the mobile terminal and by a fixed receiver (LMU) at a known position. When a signal from at least three *base transceiver stations* (BTS) is received by an E-OTD enabled handset and the measurement unit, the time differences of arrival of the signal are calculated using standard techniques in which the points of intersection of hyperbolic position lines estimate the position of the mobile terminal.

This technique requires upgrades in the handset. While similar to network-based solutions using TDOA, mobile terminals in an E-OTD system support position determination in a network where BTS are asynchronous. E-OTD technology offers positioning accuracy between 50 and 125 meters, but has a slower speed of response and requires software-modified handsets.

A-FLT (Advanced Forward Link Trilateration)

This method of location is unique to CDMA (code-division multiple access) networks, since they are inherently synchronous. It relies on measuring the phase delay between signals sent to a pair of BTS and comparing this data with the values obtained from another pair. Similar to the TDOA method of determining location, data from three base stations can be used to ascertain the location of a handset.

GPS – The Global Positioning System

Largely considered to be the most accurate long-range location-based technology (and certainly the best-known), GPS uses satellites to fix the position of a mobile unit equipped with special hardware and software for receiving their signals.[402] GPS devices comprise a receiver and a navigation computer. They accept signals from the satellites and use them to calculate the distance between the satellites and the receiver. Based on this information, the computer can subsequently determine the position (and, over time, the velocity) of the receiver.

There is more than one type of GPS system. *Differential* GPS (DGPS) is a positioning procedure that uses two receivers, a rover at an unknown location, and a base station at a known, fixed location. The base station computes corrections based on the differences between actual and observed ranges to the satellites being tracked. It can be used indoors or outdoors with high accuracy, but at a much greater cost. DGPS requires the use of satellites and radio beacons known as *pseudolites*. *Assisted GPS* (A-GPS) systems are used to overcome

401 http://lola.ftw.at/homepage/content/a40material/WhitePaper_Network_measurement_based_handset_localization.pdf

402 GPS is covered in far greater depth in *DigiCULT Technology Watch Report 2*, in particular the chapter on Mobile Access to Cultural Information Resources (pp. 91-118). A good pictorial introduction to GPS is available on the **Garmin** Web site, at http://www.garmin.com/aboutGPS/

the delay problems which can occur when locating a mobile unit. This technique relies on transmitting data about the mobile object through a network of base stations to accelerate the process of location determination, reducing it to only a few seconds. A-GPS is accurate to around ten metres, but systems can be expensive for the end-user since they require a GPS-equipped handset. The GPS handset also has to be in sight of three or more satellites, making its use difficult in built-up areas and indoors.

Acceleration based positioning technologies

Inertial Navigation System

Inertial navigation systems (INSs) estimate positions using *accelerometers*, devices which measure the acceleration of an object.[403] Accelerometers use two successive integrations in order to define the position of a moving object. Each integration step produces an output *drift* and, if the second is performed without preliminary drift compensation, the end result can contain a substantial error. In order to avoid this, the system is reset after the first integration phase while keeping the processing result. This technology is expected to become the preferred technology to be used in *WorldBoard*.[404] Unlike DGPS, which involves expensive infrastructure (including satellites and radio beacon pseudolites), acceleration based technologies represent a completely closed system that is small, lightweight, low powered and very accurate, allowing sub-centimetre position determination.

Ultrasonic location systems

These systems typically use the measured propagation delay (or *time-of-flight*) of signals between ultrasonic transmitters and receivers to determine a physical distance. A number of measured delays are taken between fixed transmitter or receiver units and the mobile device. The location of the device can be found by means of computational algorithms based on the principles of *multilateration*, the determination of a position using the time difference of arrival of a signal at a set of sensors.

Ultrasonic transmitters and receivers can be mounted at fixed locations, affixed to mobile objects or even worn by human users. Ultrasonic systems are characterised by their high accuracy (to centimetre level). Unfortunately, their implementation requires a complex infrastructure placing them beyond the budgets and technical capabilities of many users.

Ultra-Wideband (UWB) Technology

UWB is a wireless technology for transmitting digital data over a wide range of frequency bands with very low power. It is capable of sending out data at very high rates, and can carry signals through walls and other obstacles. The distance a signal can propagate is in direct proportion to its power. Instead of the traditional sine-shape waves, ultra wideband

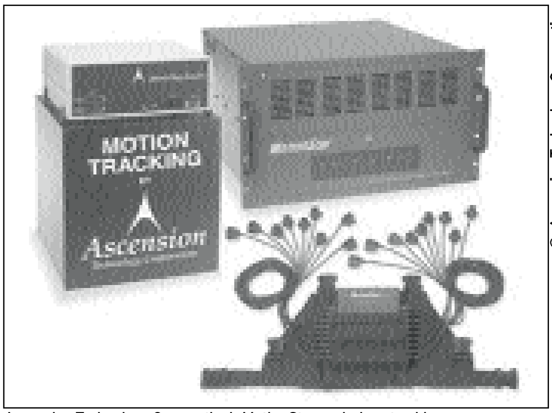
403 Positions are estimated by integrating twice the acceleration value.
404 For more on WorldBoard see *DigiCULT Technology Watch Report 2*, online at http://www.digicult.info/pages/techwatch.php

uses digital pulses which are less susceptible to interference. UWB devices can be used for wireless connection, for acquiring images of objects buried underground or hidden behind surfaces (known as *Ground Penetrating Radar*), as well as for precise measurement of distances or locations.

Magnetic field-based systems

Magnetic field-based systems use transmitter-generated DC magnetic fields to track the position and orientation of sensors. Sensors can be worn by people or affixed to moving objects and the acquired data sent through the air to the base station for further processing. Magnetic field-based systems (sometimes called magnetic *trackers*) comprise a base station, a transceiver, and a dedicated receiver. Transceivers generate low frequency DC magnetic fields while receivers (sensors) are miniature antennae where currents are induced. These currents, when sensed by the transceivers, are related to the position of the receiver and mobile object respectively. Data are sent to the base station for further processing.

Magnetic field-based systems are moderately priced and provide a good operating range without line of sight issues. Disadvantages relate to *noise* (requiring appropriate filters), d*istortion* of the magnetic field by metals or conductive materials (requiring non-linear calibration), or *interference* from nearby magnetic-sensitive devices (such as monitors). **Ascension Technology** claims that their *Motion Star* wireless trackers can define positions with accuracy of 1mm and 100% precision.[405] Their wireless suit includes twenty battery-powered sensors affixed to the human body and updated one hundred times per second. The position is defined in the 3m range of the system, accurate to around 2mm.



© Ascension Technology Corporation

Ascension Technology Corporation's *MotionStar* – wireless tracking

Location-Based Systems and the Heritage Sector

Introduction

There are a number of examples of successful application of GIS and other location-based systems in different cultural heritage institutions. The GIS Laboratory at Springfield's **Illinois State Museum** uses GIS to create and maintain a database of over 40,000 archaeological sites in the state.[406] GIS also is being used in the creation of several of its new exhibits in the coming year. The Laboratory's Web site includes a GIS animations gallery.

The **Science Museum of Minnesota** in St Paul is currently working on a series of

405 http://www.ascension-tech.com/
406 http://www.museum.state.il.us/research/GISlab/

GIS-based projects for public display and ongoing class work.[407] A kiosk on the museum's exhibit floor features interactive maps of the St Croix River valley. A Map Lab was specially established in 1997 to implement GIS technology in the museum. GIS is used in an online presentation called *Greatest Places*, which shows famous geographic objects with abundant map information and providing interactive answers to questions such as "Where is A?", "How far is B from C?", and so on.[408] The *Technical Assistance Program for Watersheds* project is dedicated to the use of geographic information system and hydrological modelling technology for the advancement of watershed research and management.[409]

The **Denver Museum of Nature and Science** in Colorado receives mapping and research support from its GIS Laboratory which supports research in zoology field research, palaeontology faunal studies and anthropological excavation findings.[410] Geographic information systems employ homemade software which links map objects – including fossil sites, river systems, and surface geology areas – to a database of information about each object.

The **Berkeley Natural History Museum** has implemented *BioGeomancer*, a program which accepts textual spatial references and automatically returns point locations, and which is specifically designed to handle data linked to natural history collections.[411] Geocoded specimen metadata are used to create GIS point distribution maps. Some 3.4% of the museum's twelve million specimens can be displayed on a Web sitemap, including specimens from the **Museum of Vertebrate Zoology** and the **University of California Museum of Palaeontology**.[412]

The **Roman-Germanic Museum** in Köln, Germany, has deployed a layered digital atlas with GIS functionality for archaeological excavations and research into the city's urban development.[413] The software employed – **SICAD**'s *Spatial Desktop* – provides detailed information on the city's historical heritage.

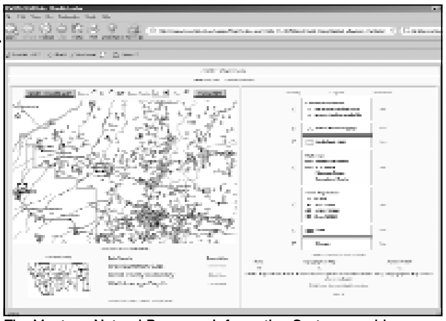
London's **Tate Modern** uses a multimedia guide based on WiFi-enabled *iPAQ* PDAs from **Hewlett-Packard** to deliver audio, video, text and graphics content depending on the visitor's location.[414] The system, which won an award for technical innovation in Interactive Entertainment from the **British Academy of Film and Television Arts** (BAFTA), uses wireless location sensing technology from **PanGo Networks**.[415]

The **Mathers Museum of World Cultures** uses *WorldBoard*, a new information and communication technology currently being researched and developed by a group of museum professionals.[416] Fundamentally, *WorldBoard* is an enhancement of the Web enabling anyone to virtually attach information to any location or object in the environment. By using a *WorldBoard*-enabled device, museum visitors can access and select from a wide range of content files (text, sound or graphical) correlated to a specific exhibit case or artefact. *MUSEpad* is a first-generation *WorldBoard*-enabled device.[417]

Penn State University Libraries provide GIS assistance for patron projects and when customised maps are required.[418] They offer a large map and atlas library (400,000 maps and 4,000 atlases, both thematic and historical), digital cartographic material including raster images and

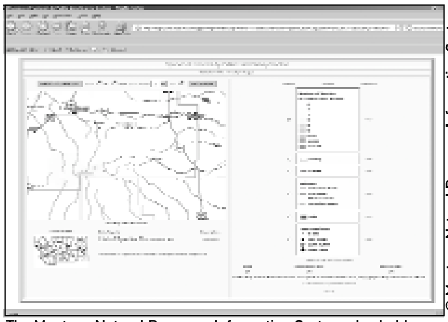
407 http://www.smm.org
408 http://www.greatestplaces.org/
409 http://www.smm.org/scwrs/harmon.php
410 http://www.dmns.org/main/en/
411 http://bnhm.berkeley.museum/; http://www.biogeomancer.org
412 http://www.mip.berkeley.edu/mvz/; http://www.ucmp.berkeley.edu/
413 http://www.museenkoeln.de/roemisch-germanisches-museum/
414 http://www.tate.org.uk/modern
415 http://www.pangonetworks.com/
416 http://www.indiana.edu/~mathers/index.html; http://www.worldboard.org/
417 For more on MUSEpad see the case study in *DigiCULT Technology Watch Report 2*, pp. 102-103.
418 http://www.libraries.psu.edu/maps/

vector images, interactive atlases, collections of geographic data and images, nautical and aeronautical navigational charts. The **Montana State Library** is home to the *Natural Resource Information System* (NRIS), established in 1985 to make information on the state's natural resources readily accessible to government agencies, business and industry, and private citizens.[419] NRIS provides expertise that helps people find, understand, and use natural resource-related information.



© Montana Natural Resource Information System

The Montana Natural Resource Information System provides dynamic maps and links to related resources.



© Montana Natural Resource Information System

The Montana Natural Resource Information System also holds natural information, including the location and concentration of endangered species.

All of these implementations of LBS and GIS in the heritage sector demonstrate the serious potential these still emerging technologies hold for cultural institutions.[420] For each of them, the use of GIS technology also has major organisational implications. Basic concerns involve the capture, management and processing of data in the actual site and on the desktop. This explains why the promotion of location-based technologies can be a long and involved process but one which has provided a clear understanding of the application areas and the business benefits alike.

There are many other possible applications of GIS and LBS technologies in the heritage sector, including:

- Direction of visitors using GIS as an information source on institutional Web sites;
- Administration and planning of museums and libraries, including assistance in service area mapping. GISs can be used to match services to visitor needs and interests by displaying demographic and statistical information together with location and service areas;
- The creation and maintenance of archaeological sites databases using GIS tools;[421]
- New ways of displaying exhibits with GIS tools;
- As a research tool for, for example, palaeontology, anthropology and archaeology excavation findings;
- Museum collection management. These can be administered more efficiently thanks to the compatibility of GIS with standard relational database tools;
- As an education tool. This need not be overly complex, and is certainly not limited to higher education. A group of young teenagers at **Jenifer Junior High School** in Lewiston, Idaho have worked on GIS mapping of their local cemetery in an effort 'to visualise a possible pattern for the reburial of graves that were exhumed during 1889-1890 when the cemetery was moved to its present location'.[422]

419 http://nris.state.mt.us/gis/default.htm

420 For an example of an innovative new application, see "3D-ArchGIS: Archiving Cultural Heritage in a 3D Multimedia Space" in *DigiCULT.Info*, Issue 6, December 2003, pp.6 http://www.digicult.info/pages/newsletter.php

421 See for example the **Electronic Cultural Atlas Initiative**'s *TimeMap* project, which combines GIS and visualisation techniques to filter and deliver potentially huge volumes of humanities data. See the section on Visualisation of Data, below, for a case study on this work. URL: http://www.timemap.net/

422 http://www.lewiston.k12.id.us/sbranting/5thCem/pre.htm

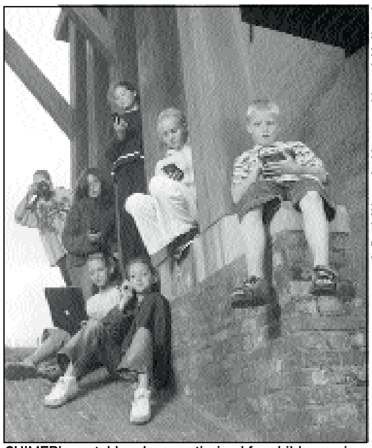
For the cultural heritage sector, location-based systems are found increasingly in museums, galleries and general exhibits for a variety of purposes, such as:

- Enhancing visitor experience using dynamic location-based content;
- Providing access to specific content in relevant rooms, galleries or exhibits;
- Improving visitor services by providing information on nearby facilities such as restaurants and gift shops;
- Providing tour management information. For larger groups this may mean improved security thanks to location tracking capabilities. For planners, visitor traffic analysis can be conducted in order to determine the most frequented galleries and general usage patterns;
- Helping users accessing relevant content from the Web during museum tours;
- Improving accessibility for visitors with disabilities or other access issues.

Case Studies

CHIMER – Children's Heritage Interactive Models for Evolving Repositories[423]

CHIMER is an EU part-funded project aiming "to capitalise on the natural enthusiasm and interest of children in developing new approaches to the use of evolving technologies for documenting items of cultural interest in their local communities".[424] Under the supervision and guidance of teachers and heritage experts, children from different parts of Europe can use CHIMER's systems to build digital maps which combine GPS coordinates with the innovative use of new mobile technologies and digital cameras, linking photographs with their own comments and thoughts on what they encounter in the field. In this way, children collaborate to build a virtual Digital Heritage Archive of their own towns and communities which should enhance interest in these regions for childrenand adults alike, and for future users.


© Bedrijfsregio Kop van Noord-Holland

CHIMER's portal has been optimised for children using a range of mobile devices

CHIMER's work involves collaboration between technical experts, museological researchers and schoolteachers. The information provided by museum experts and teachers is complemented by children's own interpretation of the materials. Young people often have an easier relationship with new technologies than their elders and the project supports children's natural creativity and curiosity by encouraging the exploration of new tools for digital content creation. The methodology used by the project encourages children to learn how to obtain and pass on information, as well as how to format it in ways that will be both useable and appealing to others.

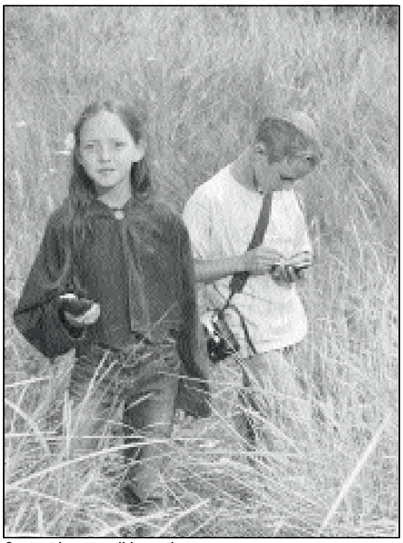
The CHIMER consortium consists of fourteen participating organisations, with responsibilities ranging from content provision to application development, testing and evaluation. The partners are: scientific and administrative coordinator **Stichting Bedrijfsregio Kop van Noord-Holland** and **Groene Poolster** in the Netherlands; technical coordinator

423 This case study is based on material available from the CHIMER Web site, and elsewhere on the Web. All references are given in footnotes. http://www.chimer.org/index.asp
424 http://eschoolnet.eun.org/ww/en/pub/eschoolnet/teachlearn/teachersfavourites/weissfavourites.htm

CIBERESPACIO SL, CRA Nosa Sra do Faro, and **mudima**, Spain; **Zentrum für Graphische Datenverarbeitung e.V., Friderico Francisceum Gymnasium Bad Doberan** and the **Fraunhofer Institute for Computer Graphics**, in Germany; the **Institute for Advanced Management Systems Research** at **Åbo Akademi University**, Finland; the **State Research Institute of Applied Mathematics and Informatics** and **Vilnius Minties Secondary School**, in Lithuania; **Chanovice Elementary School, Okresní muzeum v Klatovech**, and **CROSS-CZECH**, from the Czech Republic. [425]

The project has three main location-based information service deliverables: an E-map, a mobile guide, and an electronic guide. The *E-map* is based on a vector map in digital format. It is used by children, teachers and museum staff to select places of interest for inclusion in the project using geographical data collected from a GPS device. At the same time, children track and record waypoints along the route between places of interest. These data are then downloaded and merged with the vector map of the selected territory allowing them to be retrieved by mobile users. The *M-guide* (mobile guide) is CHIMER's Application Programmer Interface (API), a multilingual multimedia tool manipulating the content stored in the Digital Heritage Archive and linked to the E-map. It is essentially a wireless, personal multimedia system for accessing geographical heritage information services. The *E-guide* (electronic guide) provides a similar function to the M-guide for static Web users linked to the Digital Heritage Archive and E-map.

The systems combine numerous location-based technologies (GPS, GPRS (General Packet Radio Service), WiFi, and GIS) via the Internet. The aim is to develop interfacing and user access tools specifically for evolving third generation (3G) networked multimedia technology to retrieve local heritage resources. CHIMER is therefore able to provide roving users with dynamic maps via the Web, GPRS/3G or WiFi, providing information about current surrounding and making suggestions on nearby attractions, facilities and places of interest. Children can also use mobile phone camera facilities to take a picture of a building, for instance, and send it via the Multimedia Messaging Service (MMS) to a local information service which then uses the attached GPS coordinates to provide information about the building and routes to similar places of interest in the vicinity.[426]



Content is accessible on the move

Children and teachers can query the digital archive via CHIMER's three Web applications: the E-map, E-guide, and M-guide. Each of these can be accessed using standard HTML Web browser or via mobile applications using a specially designed XML/Wireless Markup Language (WML) protocol. This protocol can easily be extended to handle the implementation of new features. In deployment, WiFi hotspots have been set up in the **CRA Nosa Sra do Faro School**, Spain, and at

425 http://www.bedrijfsregio.nl/; http://www.groenepoolster.nl/; http://www.craescuela.net/; www.mudima.org; http://www.zgdv.de/zgdv; http://www.gff-dbr.de/; http://www.igd.fhg.de; http://iamsr.abo.fi/iamsrweb/iamsr/; http://www.science.mii.lt/; http://www.retour.cz/mesta/klatovy/muzeum.htm; http://www.crossczech.cz/

426 http://www.cultivate-int.org/issue8/chimer/

Stichting Bedrijfsregio Kop van Noord-Holland, the Netherlands. A GIS platform has also been developed which serves multimedia information (still images, audio, video, vector maps, routes for GPS or Arc Pad Pocket PC shape files, and satellite images) to a range of hand-held devices. Indeed, the portability of information across different platforms is one of CHIMER's key goals and the system is compatible with any Pocket PC, Tablet PC, or next generation Ericsson/Samsung/Nokia 60 series of Java-based mobile phones.

In short, CHIMER focuses on cultural tourism as a sustainable development with cultural heritage materials as an intrinsic base. The project hopes to suggest a model which may be "replicated in other networks, not only in the area of culture but also, for example, for public sector information, health, tourism, based on the use of digital cartography linked to multimedia data".[427] Work began on the project in March 2002, and was expected to be complete in late 2004. The total project budget is €2.14 million, of which €1.37 million came from the EU.[428]

ODIN Mobile[429]

The rise of the cellular market in Europe has lead to a demand for 'value-added' services to be delivered through digital wireless devices such as mobile phones, PDAs and other handhelds, and laptops. New map-based Web services providing interactive, personalised information have already proved popular in European rural areas.[430] The *ODIN Mobile* project aimed to develop innovative paradigms for the design of open, distributed, and networked tools to boost the integration of an entire new class of just-in-time (at the point of need), interactive, value-added, map-based and personalised services for the mobile users. It paid special attention to the promotion of the natural and cultural assets of rural areas.

The project ran from April 2000 until September 2002, and sought to satisfy the emerging requirements of an increasingly mobile set of information users and their new demands on integrated and tailored information services. Subtitled 'Geographic Distributed Information Tools and Services for the Mobile Information Society,' the project was split into two parts: a toolset for visualisation and use of services, and a list of services linked to specific locations or zones. Project goals included:

- Defining a global system architecture for the delivering platform and services that comply with Open Distributed Processing guidelines;
- Contributing to work in defining standards on spatial data interoperability;
- Implementing an integrated ODIN toolkit for accessing spatial and non-spatial information using XML and Java, and delivering it to hand-held devices;
- Specifying, developing, and validating intelligent services (e.g. for administration, business, environment, transport, weather, culture and leisure) for mobile business or private users, aiming to raise the quality of life and business activities of rural areas in particular.

ODIN project partners were: **Arpat, Sovrintendenza Belle Arti, Telecom Italia Mobile**, and **T&T** (Italy); Autodesk (Germany); **The Egnatia Epirus Foundation,**

427 http://www.im-boot.org/modules.php?name=News&file=article&sid=603
428 http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&CALLER=PROJ_IST&QM_EP_RCN_A=61828
429 This case study was researched using material from the project Web sites during August 2004. http://odin.vestforsk.no/pc/ and http://www.odinproject.org/, http://www.avinet.no/balder/default.asp
430 For example, the TITAN project (TRANSMODEL-based Integration of Transport Applications and Normalisation) funded under the EU Fourth Framework Programme. For more on TITAN, see http://www.transmodel.org/en/prestit.htm

Emphais Systems, and **Epirus Regional Government** (Greece); **EIAT Ireland, Eircell**, and **The National Microelectronics Applications Centre (MAC)** (Ireland); **Omicron Technologies** (UK); **Fylkesmannen i Sogn og Fjordane (SFCG), Fjordane Municipality, Telenor**, and the **Western Norway Research Institute** (Norway).[431] The collaboration between these institutions is one of the project's major strengths. The complementary expertise and experience of medium-sized IST system integrators, large telecommunications operators and digital information developers has been beneficial in enabling the delivery of spatially enabled tools and services to users. The fact that the project partners included national and regional administrative bodies with an interest in utilising the finished platform and services was also helpful. The locations covered by the system reflect the origins of its partners and each service is adapted to local areas to meet project goals fully.

Approaches to the work were based on the following principles:

- To define tools, functionalities and information services, input is needed from existing service providers;
- Tools and services must conform to existing and upcoming standards;
- ODIN partners have already gained expertise from research and the development of commercial products. Project work can use existing knowledge to develop the field further;
- Ongoing evaluation and assessment activities are vital in order to assess the progress of the project. This includes a demonstration process to refine and assess the project results, acting as a field trial for real life situations and uses.

The project was divided into five stages:

(I) **User Requirement and Global Design Phase**, where market research was performed, user requirements collected and the system's global design considered;

(II) (**Design and implementation of the ODIN ToolSet** using the iterative development cycle. The ToolSet comprised an Information Connector tool that gathers data, an Information Manager tool which acts as an information hub and the Information Visualiser tool (based on extensions of the **Autodesk** *MapGuide*[432] tool suitable for mobile devices) which provides the front-end delivery service for all data and information handled by the Information Manager;

(III) **Design and Implementation of the ODIN Services**, comprising validation of the toolset, and the production of relevant services;

(IV) **Demonstration**, a valuable tool for testing and refining the tools and services already implemented; and

(V) (**Evaluation** by self-assessment. A formal review of the project took place during the 30th month, and a full-product demonstration took place in April 2002.

ODIN uses various processes such as wireless connection technologies, Global System for Mobile Communications (GSM: cellular phone technology), General Packet Radio Service (GPRS) XML, GIS, GPS, and **Microsoft**'s *.NET*. Although services are designed for delivery on mobile devices, all are available through a user's desktop PC. Users create a profile, allowing them to access services when they visit particular regions. The services are delivered

431 http://www.arpat.toscana.it/; http://www.tim.it/; http://www.autodesk.de; http://www.epcon.gr/metsovo/egnatia/egnatia.htm; http://www.emphasis-systems.gr; http://www.eircell.ie; http://www.mac.ie; http://www.telenor.com/; http://www.vestforsk.no/

432 http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=2995478

according to the location of the user (detected automatically by cellular telecommunication technologies or entered manually by the user), and are tailored to individual preferences.

ODIN Mobile's total budget was €956,848, €350,959 of which came from the EU. The success of ODIN has led to further work in a second project, BaldeR (Bringing Accessible Location-Based services to Regions). Institutions involved in BaldeR were the **Western Norway Research Institute** and **Asplan Viak Internet A/S** (Norway), **Munin** (Faroe Islands), and **Icelandic Farm Holidays**.[433] BaldeR's main aim is to verify the usability of mobile location based services in rural areas, specifically exploring the potential of this technology in the tourism sector.

Atlante Italiano[434]

The *Atlante Italiano* (Italian Atlas) project was launched in 2001 by the Direction General for Soil Preservation. It was created to provide online access to the cartography of the whole Italian national territory via a portal for viewing Italian maps organised under different perspectives, e.g. environmental risks as flooding, earthquake, and so on.[435] The system was developed under contract from the **Ministero dell'Ambiente e della Tutela del Territorio** (Ministry for the Environment and Preservation of the Territory).[436] The Ministry's primary purpose is to preserve the soil in a country where hydrogeological damage, earthquakes and other natural disasters pose a significant risk for the national territory. For all these tasks – including guidance, control and funding – precise and up-to-date knowledge of the territory has always been crucial, and cartography is one of main instruments for reaching this goal.

The archive, which is complete for the entire country, comprises topographic maps and aerial images conforming to the *Universal Transverse Mercator* (WGS_84) global grid reference system.[437] The online portal allows access to topographic maps at a low scale (in the order 1:1,000,000, 1:250,000, or 1:100,000), medium scale (1:25,000), and high-resolution aerial images (1 pixel per meter), both in black-and-white and in colour. It is also possible to access basic laye rs or thematic laye rs containing the information currently available at a national level, facilitated by the related administrations. These include hydrogeological risk maps, protected areas such as national and regional parks, soil utilisation and ecopedological maps.

While the idea for the Atlante Italiano portal originated within the Ministry, the challenge of the project goes far beyond what could be done using in-house expertise. The system was consequently developed by a group of specialists in collaboration with outside institutes and private companies. This means that the Atlante Italiano system cannot be maintained without the support of external consultants, but at the same time it alleviates the need for the Ministry to maintain a staff of professionals with very specific competencies. The partnership which developed around the project is the result of linking a network of existing institutions, where funding and specific operational goals play a strong role.

The location-based technologies involved in the project include satellite imaging, stan-

433 http://www.asplanviak.no/, http://www.munin.fo, http://www.farmholidays.is/
434 This case study is based on interviews between representatives of **Ministero dell'Ambiente e della Tutela del Territorio** and Paolo Buonora of DigiCULT's Steering Committee. The interviews took place in September 2004. Acknowledgments to the Ministry for the Environment and Preservation of the Territory - Direction General for Soil Preservation for all information and support. http://www.minambiente.it/
435 http://www.atlanteitaliano.it/
436 http://www.minambiente.it/Sito/home.asp
437 WGS_84 refers to the 1984 revision of the *World Geodetic System*, a standard global reference frame.

dard GIS, Web GIS, and digital imaging. The system supporting the portal is based on a Microsoft *SQL Server* database, a digital collection of vectorial and raster (ECW) images, an **ESRI** *ArcIMS* image server, and application software also developed by ESRI.[438] Today's market offers a wider range of potential technologies than those employed, but at the time of the project implementation the choices were very limited: a technology solution was necessary to make georeferencing cartography available online in both raster and vectorial formats. The cartographic themes were managed and developed by the technical staff of the Ministry. **ESRI Italia** and **Planetek** and developed the standard software used to develop these cartographic functions.[439] The main features of the systems were high reliability, a modular architecture, and horizontal and vertical scalability.

The system is still fairly new and the hardware and software are up-to-date, so no work is currently needed to update or preserve it. One problem which may occur in the future concerns migration. The system is huge, containing a massive amount of data, in the region of 3 Terabytes, and growing further in the future. It is possible that an emulation strategy will be the best eventual solution to this problem, emulating only the application software and keeping the original bit stream intact.

The Web portal was launched in 2002, and those responsible for the project are quite satisfied with its success: it is accessed by an average of 15,000 users per day. By 2006 most public cartography producers and services will be involved in portal activities, and a systematic work to announce and disseminate the project to the users will begin. The cartographic portal is also a starting point to catalyse resources that are available elsewhere. The project deals with a huge amount of resources, in other words all the cartographic assets and all the professional knowledge available in national and regional administration. Government legislation gives the Atlante Italiano an important role in the context of the production of cartographic information. Atlante Italiano is also part of the European project *INSPIRE*, which promotes the linking and upgrading of cartographic resources.[440]

Atlante Italiano is closely related to the *Risk Map* project, carried out by the **Istituto Centrale per il Restauro** (Central Institute for Restoration) since the early 1990s with the aim of providing the authorities in charge of safeguarding the national territory and the central administration with a technological instrument supporting scientific and administrative work.[441] This activity aims to prevent damage to monuments and buildings from earthquakes, floods and volcanoes, as well as safeguarding the cultural collections that are hosted inside. Integration between the cartographic assets and GIS resources developed by Risk Map and Atlante Italiano would be highly desirable. Another possibility could be the integration of Atlante Italiano with projects which hope to link all cultural heritage and activities on location-based systems, at the same time supporting the tourist sector, which is very important in Italy.[442] The digital assets developed in digital libraries or archives to provide a virtual access to historical cartography would benefit from a link with the contemporary cartographic services accessible in the Atlante Italiano. It is felt that the possibility of using geographic coordinates may be more helpful

438 http://www.esriitalia.it/; http://www.esri.com/software/arcgis/arcims/
439 http://www.planetek.it/
440 http://inspire.jrc.it/home.html
441 http://www.icr.beniculturali.it/rischio/rischio00e.htm
442 Development of an official portal to promote tourism and culture in Italy was officially announced by Lucio Stanca, Minister for Innovation and Technologies, in Rimini in March 2003. http://www.interno.it/news/pages/2003/200303/news_000019358.htm

and faster for retrieval than the alternative geographic names index or thesaurus.[443]

The project had a total budget of around €40 million, including the funds needed to purchase cartography produced by private enterprises; resources from official boards like the IGM and Geographic Military Institute were supplied free of charge. The work involved about thirty persons, almost all of whom were private consultants and contractors. Work to increase the amount of resources available through the portal remains ongoing, with the eventual goal of allowing user access to digital cartography wherever it is produced and available on the Web, expanding the existing technology and access procedures.

Scenarios

GIS Tracking of Social Development over a Period of Years

In May 2004, ten new countries entered the European Union. This was the first time that such a large number of states had joined simultaneously. The event created excitement among academics with sociological, anthropological and economic backgrounds who saw this as an excellent opportunity to gather data for future scholarship. The academics determined that while all countries experience continual change it was likely to occur faster and with more noticeable results in these new states. As a wide variety of information was of interest, GIS seemed an ideal way of storing the data in an organised and coherent manner. The academics, aware that the project would benefit from time and the gradual increase of data, decided to base their system on the widely used open source *GRASS* package,[444] hoping the open-software and format paradigm would assist long term access to the data stored within.

Collection of information was initiated and continues to be accepted from a variety of sources. As regions undergo significant structural and economic improvements, authorities hire contractors to undertake studies investigating the connectivity of adjacent townships, the reservation of land for public services and the location of existing historical places which must be reserved. They attempt to project the sustainability of the increasing populations on local resources such as water and gas distribution networks. Existing sources such as local academic and government institutions are found to contain large quantities of re-usable data. The storage of information as a layered database allows queries on subsets of data to be selected and executed at a later point in time, enabling the academics to store as much information as possible. Simultaneous to the collection of environmental information, sociological and economic information is collected in GIS-compliant form. This data covers topics such as population densities, salary variations and employment rates and is inserted as coordinates sets attributed to certain regions. The data stored in the GIS originates from trusted sources, guaranteeing a high level of accuracy. Along with a high level of accuracy, it is essential for the data to conform to a single scale of dimension. On several occasions, data translation into a standard coordinate system is required.

The resultant GIS is highly scalable, enhancing the possibility of distribution to a variety of geographic locations. After a period of time, the member states continue to flourish and remain a significant interest to the founding countries of the EU.

443 Examples include the Geoweb system in the Marciana Library in Venice http://geoweb.venezia.sbn.it/geoweb/gwindex.html, and the Imago systems at the State Archives of Rome http://www.asrm.archivi.beniculturali.it/English/index.html.

444 http://grass.itc.it/

A small consortium of cultural heritage institutions decides to create an exhibition highlighting the exciting changes the new member states have undergone. The consortium requests, and is granted permission to use the collected GIS data and spend some time developing and configuring an existing open source visualisation utility to work with the GIS acting as a novel feature to tie sections of the exhibition together. In turn, the academics make subtle developments to the open source utility allowing comparisons of visualisations of regions, highlighting previously unnoticed relationships between areas. While it takes some time for the benefits of the work to become visible, all of the participants are pleased with the continuing development and expansion of the project.

GIS and Archaeology

The Limes, the fortified Roman frontier line, is the biggest archaeological object in Central Europe.[445] The Limes were constructed over a period of 100 years and, rather than maintaining consistency in construction, contained many local variations depending on the topography, province, date of construction, and seriousness of the threat from the Germanic side. The structure was designed to mark the Roman frontier and prevent unrecognised entry from Roman territory. The design was used as a basis for later Roman frontiers, such as Hadrian's Wall crossing northern England, and the Antonine Wall crossing the central belt of Scotland.

Around twenty forts and several hundred watchtowers protected the 100km final Upper Germanic line. Forming a near perfectly straight line, there are still many theories about how construction occurred without consideration of the topography of the landscape. A team of archaeologists would like to create an exhibition demonstrating the elegance of the design of the Limes as a whole, the placing of the individual structures built into and placed alongside the Limes and the planning that must have occurred in order to achieve their construction and maintenance.

The team decides that the commercial *ArcGIS* package will be used to store data on the scheme upon which the Limes were built and begin their implementation of the system.[446] The base layer is to detail the geographical topography of the region and suitable maps are collected from local cultural heritage institutions. Using data from a variety of surveys, the archaeologists detail the locations of the lines and add annotations detailing how they were built, rebuilt, fortified and moved over time. Members of the team are selected to introduce additional resources on Hadrian’s and the Antonine Wall, creating a shared memory of the Roman Empire in Germany, Scotland and England. Having created the geographic database to store the information, the team develops a Web-based delivery and management service to enable geographically distributed users to access the system.

An ambitious idea is suggested by one of the members of the team and is very popular with the group. He would like to visualise the views that could be obtained from lookout posts, showing how the fields of sight overlapped at many of the watchtowers to create a continuous view over the landscape … an environment through which it was difficult to enter undetected and which allowed messages to be rapidly transmitted in response to enemy attacks. To generate complex visualisations such as this, information stored must be recorded to the same scale and accuracy. This issue is known as data smoothing.

Depending on the method of collection, maps have different accuracies. Upon investiga-

445 http://home.t-online.de/home/bernd.hummel/limeng.htm
446 http://www.esri.com/software/arcgis/index.html

tion, the team discovers that the archaeological information collected is acceptably accurate, however the geographical maps are not detailed to a suitable degree. After a further search of the original cultural heritage institutions, a satisfactory map is discovered and the team begin building the overhead visualisation. The initial progress into this work is promising, and the team is excited at the potential extensions to this work. Some members of the team dedicate a small amount of time researching the possibility of extending the overhead view of lines of sight into a Virtual Reality visualisation of the scene. This will allow users to absorb the scene from a set of alternate view points simulating the original environment.

GIS Layering and Landscape Changes

The archaeological remains of the Minoan palace of Phaistos overlook the Messara plain on the island of Crete. Earthquakes caused the destruction of the site on several occasions but each time immediate rebuilding followed. The positioning of Crete between Europe and Africa, combined with a mountain range most prominent in the West, results in an unusual climate with a wide variety of indigenous flora and fauna. A local archaeological heritage society wishes to document the ways in which the palace's environment was crucial to its development, maintenance and eventual downfall. It is decided that the site will host a display detailing the history of development and environment for the region.

A member of the board suggests using a Geographical Information System to collect the information. He comments on the ability of GIS to store multiple layers of information clearly and concisely, allowing alternate layers to be selected at the point of delivery. The board likes this idea, suggesting it may enable visitors to detect subtle relationships and patterns that would otherwise be difficult to explain. The board creates a task force to investigate use of a GIS to represent the information.

The task force look at GIS alternatives. The budget allocated to the project is limited, in part due to the trial-like nature of the project. After some consideration, the team select *GRASS* to store the information. An appropriate coordinate system is selected to ensure information from different sources will match up. Following this, the task force begins to compile a variety of information. A topographical vector map of the region generated by GPS is obtained from the local university's geography department. In conjunction with archaeologists, GIS surveys of the palaces are collected from local libraries showing to a high level of accuracy where improvements were made and existing structures re-used after earthquakes. Wind patterns are collected from existing meteorological databases and data are entered detailing how the site of the palace is protected from the northerly winds that predominate each winter. The local environmental agency provides mapping information on the range of the fertile lands that surround the site along with data on the water sources. The irrigation and sewage system for the palace was impressive. It was operating in the time and region where the principles of hydraulics were discovered.

Data on this is collected from archaeological sources. As each of the datasets contains vector-based information, the conversion of this information into a visualisation is relatively simple. The resultant system provides an initial focal point upon arrival at the site and serves as an introduction to the features of particular interest. Visitors enjoy using the service and the board decide to install it at several other local palace sites.

GIS systems often contain information that is useful for multiple purposes. The local natural history board hopes to provide information about the exquisite variety of flora and fauna on the island and a member suggests collaborating with the archaeologists and gaining access to existing data. He hopes to manipulate the existing data and combine it with additional information relating to the habitats and environmental conditions of the island. The suggestion is met warmly and after an initial proposal, both groups feel that this may be a rewarding partnership. They look forward to the future.

GPS as an Aid to Visitor Studies

The manager of a built heritage centre is concerned with the erosion and damage that is being caused by increasing numbers of visitors. The manager wishes to determine which areas of the site receive heavy visitor traffic and hence which paths must be more carefully monitored. It is hoped that this study will allow an analysis of the visitor flows, while simultaneously providing reusable data to help in gaining a better understanding of the situation and means of dealing with it.

Radio frequency identification (RFID)[447] is unsuitable for this task due to its low accuracy, the number of transceivers required and their visual conspicuousness. As an alternative, portable GPS receivers are suggested. To improve the accuracy of a GPS system, a static receiver can be used as a local control point for calibrating the mobile devices. This technique, called differential GPS, is suitable where close tracking of visitors is required.

The control point is to be located in the administration office of the centre. It is decided that a GPS receiver will be given out to each group of visitors. Before a device is handed over it is checked. This requires connecting the device to the main system via USB, deleting existing information and reinitialising the device, allocating a temporary but unique identifier. The portable device used by the heritage centre shares some functionality with a PDA. It contains a very simple questionnaire that users are asked to fill out, requesting the age and number of visitors in the group along with a query about the weather conditions.

Location information is transmitted from GPS satellites approximately every thirty seconds; this enables frequent tracking of visitors to be maintained. With differential GPS, the system is accurate to between one and five meters. For the purposes required, this accuracy is adequate. Additionally, the high frequency of data will allow the manager to see not only where the visitors are going, but also how long they are spending at each area. Assuming visitors to the heritage centre spend an average three hours at the site, approximately 360 coordinates are recorded per visitor. This is enough information adequately to track visitors and should not flood the system.

The GPS device does not require any input from the user to collect the spatial information. Upon returning to the exit, the GPS devices are handed back to the front desk and the information is uploaded into a centralised GIS database using the USB connections of the device. While most of the required functionality is provided by the GPS and GIS software, some additional scripts are required to streamline the process. The primary problem is relating the information collected about the visitors to the geospatial information recorded. The GIS system in use is configured with an SQL database at the back end. When the manager asks the IT team to study the problem, the staff adds an additional table relating the customer information to the coordinates obtained. A *Perl* script is added to the GIS utility, depositing the additional information in the required location. A visualisation package is then used by the manager to study the flow of visitors to the centre.

447 RFID technology is extensively covered in the chapter "Smart Labels and Smart Tags", *DigiCULT Technology Watch Report I: New Technologies for the Cultural and Scientific Heritage Sector* (2003), pp.63-93. Available online at http://www.digicult.info/pages/techwatch.php.

This scenario continues in the section on Visualisation of Data, below

Advantages and Disadvantages

Introduction

Still very much an emerging technology for most institutions, GIS and other location-based services raise a number of issues. The introduction of these technologies can be expensive, the learning curves may be steep and the technology is likely to place high demands on storage space and other computer resources. On the other hand, location-based systems are attractive and powerful with a true potential to revolutionise the way we look at the world and solve the world's problems. The technology is here to stay and, as costs continue to fall, the question for many cultural institutions is not *whether* they will offer GIS-based services but *when* and *how*.

Advantages

Presentation –Making information more accessible and easy to understand is a fundamental aim of heritage institutions and GIS can help organise and present information in ways that ensure better understanding of places, processes, and events. GIS and technologies like virtual and augmented reality can be used together in museums to provide information about items that are not on display due to space constraints or preservation issues.

Visualisation – Cultural institutions can use GIS as a gateway to information that has in the past been difficult to portray or convey. Maps, atlases, digital aerial photographs and satellite images provide an opportunity for the interpretation of collections to be enhanced significantly and, with other specialised tools, the exploration of collections. GIS can also be used to highlight previously unrecognised spatial relations or distributions.

Accessibility – GIS is well suited for providing access to institutional content via distributed networks like the Internet. This may take the shape of an introductory presentation for potential visitors or as means of access for people who cannot visit the institution.

Integration – Institutions that already use a collections management system can integrate a GIS with the existing system, joining the contents of both systems together and teasing out new interpretations of data.

Disadvantages

Costs – GIS and other location-based systems can be expensive and require a good deal of maintenance and attention. This may place them outside the reach of more modestly sized cultural institutions. Additionally, it may be a significant amount of time before an organisation realises an acceptable return on investment from the system.

Expertise – Staff training costs are likely to be high. The software can be difficult to master, so dedicated staff may be required to administer the system.

Content issues – Up-to-date digital spatial information is likely to be under copyright and licensing of content may be required to populate a GIS. Producing content is a detailed job and cannot be taken lightly.

Lack of standardisation – GIS uses a number of different datasets and development of industry standards will be crucial before meaningful results can be obtained.

Introducing the Technology

Selecting a Specification and Development Environment

Before introducing GIS or other location-based services into an organisation, decision makers must have a clear idea about the project's aims and the development steps that it will involve. A number of questions, given below, must be answered. Choices and answers should take into account prior analysis of user needs and capabilities:

- Does the organisation have a clear vision on the conceptual transformations that may result from the introduction of the technology?
- What will be the scope of new services offered?
- Where will the services be located and how will they interface with existing systems?
- For GIS implementation, how will the geo-referenced data be acquired, stored and maintained? To what extent will data be purchased or depend on donations, barter arrangements and other such schemes?
- Will collaboration be necessary and, if so, how will collaboration strategies be realised? With which type of organisations/institutions should partnerships be established?
- What kind of data will be of interest from the GIS, and what formats wil be required? This must take into consideration the formats with which users are familiar and comfortable.
- What are the implications of copyright and licensing restrictions for the implementation, and how will these be handled?
- What will be the level of assistance provided by the staff? What training will be required?

Technological Infrastructure Issues

Introducing location-based technologies will require significant amounts of dedicated hardware and software, as well as specialist expertise. The following stages are typical for the development and rollout of location-based systems:

1. Preliminary research, including a survey of other comparable institutions with relevant experience;
2. Formal definition of goals and requirements;
3. Choice between various alternatives, e.g. specific positioning technology versus a dedicated GIS application;
4. Practical work on installations of hardware and software;
5. Staff training;
6. Testing;
7. System deployment;
8. Monitoring of system efficacy and value, and technical- maintenance, over time.

Location information can be processed by specialised network architecture. A Mobile Positioning Centre (MPC) can be used to gather and manage positioning information and to interface with applications that make use of it. A Gateway Mobile Location Centre (GMLC) controls all procedures related to the authorisation, authentication and billing of users. It also can deal with issues such as privacy. Both types of centre typically use GIS data to control the location aspects of the network and to supply services.

The architecture adopted by most network providers is based upon GMLCs. The location centre separates the location determination technique from the application where the location information will be put. Since many applications operate well with COO-based positioning data, operators can set up advanced location technology progressively, thereby negating the need to wait for the new services.

Staff and Policy Issues

Many location-based deployments will require dedicated in-house technical expertise. This will mean either hiring specialists to operate the systems or training existing staff. New staff duties will include collection development, data acquisition, service management, resource provision and partnership establishment. In more complex cases it may be advisable to contract specialist GIS consultants.

GIS technology is intrinsically complex, and learning involves a steep curve. It is essential that training and staff development is included within the GIS implementation program. The best time for this is prior to rollout. There are an increasing amount of dedicated resources available to assist in this. GIS is well described in literature and there are numerous tutorials on the Web. Free software is available to assist in initial staff learning.

Visualisation of Data

Executive Summary

Visualisation is the process of representing abstract information in the form of images that can assist in the understanding and analysis of the data. The best visualisations convey large amounts of information in a smaller space than can be managed in text. Maps, for example, fulfil such a function, as do workflow diagrams. David Staley's recent book *Computers, Visualization, and History: How new technology will transform our understanding of the past* (M.E. Sharpe, 2003) provides a wealth of examples of the current and potential uses of visual forms in the heritage and education sectors.

Visualisation systems allow people to observe large amounts of complex data, rapidly to find the information they want, to navigate and interact with data more easily, to identify patterns and trends, and to get a better understanding of the information. An immediate difficulty is that of interpretation: it takes less work to make text definitive than to make it ambiguous whereas images are more likely to be subject to wider interpretations and disagreement.

Dynamic objects refer to any objects which change over time. Such four-dimensional objects have attendant issues including the tracking and archiving of changes. We must be able to refer to past and future states of the system (time viewing); to change the structure and behaviour of an object or system (evolution); and to model semantic relations between objects at different stages and in conjunction with their associated metadata. These semantic relationships can be represented using visual *ontologies*, allowing users to explore the links between concepts in intuitive and navigable ways.[448] *Topic maps* meet a similar function, providing a means for visualising knowledge interchange between systems and disciplines.[449]

Dynamic visualisation is often used for quick analysis of fluctuating stock market data. This can assist in fostering new ways of thinking, knowledge acquisition and decision-making. Dynamic visualisations capture attention and provide a more tangible and visceral experience. Dynamic visualisations may open visitors' eyes to, for example, changes and shifts in populations. This may be of particular interest to the museum sector although the need for constantly shifting information is less pressing. But to what uses could this be put by the heritage community, i.e. what moves so quickly in our sector? One potential answer is visitors to cultural institutions. Dynamic visualisation could be used in conjunction with RFID to model the flows of visitors around a museum, for example, and how this alters according to the time of year, the artefacts on show and even the signage within the building.

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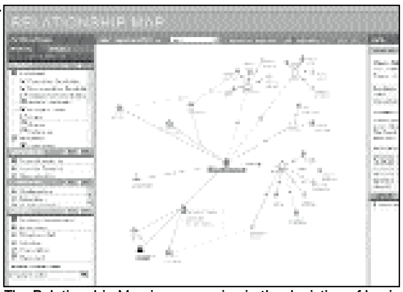
448 **Semagix**'s *Freedom* is one platform which combines semantic representations with visualisation techniques. http://www.semagix.com/solutions.html

449 See http://www.topicmap.com and http://www.topicmaps.org for much more on topic maps. **Ontopia**'s *Omnigator 007* is a free topic map navigator, which showcases their potential. http://www.ontopia.net/omnigator/models/index.jsp

© Thinkmap



The Relationship Map is an exercise in the depiction of business relationships using an intuitive graphic interface.

This topic area overlaps with many others. To provide one example, virtual reality (VR) modelling for design is already in place and this approach (often combined with tactile interfaces) looks set to dominate in the future. For an illustrative example of the overlap between visualisation, geographic information systems and virtual reality, see Zach, C. *et al*. 'Modeling and Visualizing the Cultural Heritage Data Set of Graz.'[450]

The case studies featured in this report range from the innovative historical visualisations of **Vicodi** to Stephen Malinowski's spellbinding work with the **Music Animation Machine**.

Introduction to Visualisation

Background

In general, to *visualise* means to form a mental image of something not currently visible or apparent or to create an abstraction or metaphor as an aid to comprehension. *Data visualisation* is the act of presenting precise information in a graphical form in order to facilitate its understanding.

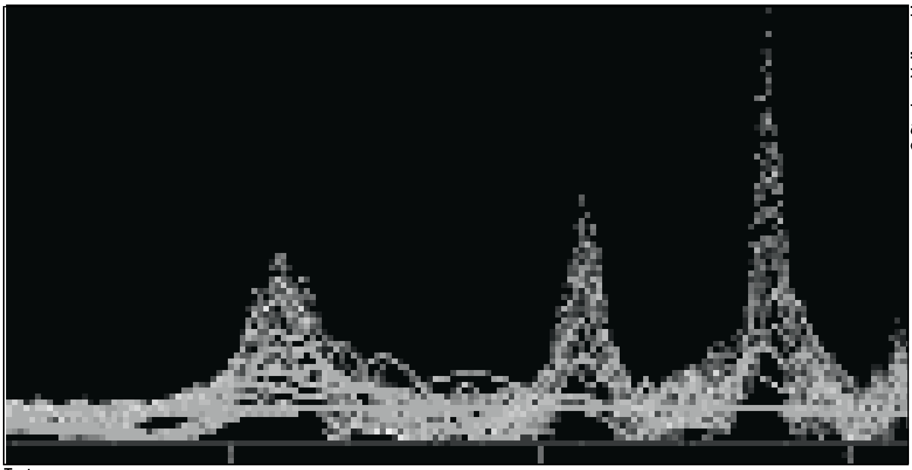
We can distinguish between numerous different kinds of visualisation. *Information visualisation* is the general term, describing the entire subject. Almost anything that is suitably structured can be considered as information. Visualisation tools offer methods for finding answers to specific queries and for uncovering hidden meanings or relationships within an information set, thus making apparent what was previously hidden. The term 'information visualisation' is generally used for the representation of non-numerical data.

Scientific visualisation is concerned primarily with the exploration of data related to science and engineering and the representation of 3D processes. The emphasis here is on realistic depiction of volumes, surfaces and light sources. It shares common ground with topics like virtual reality.[451]

Data visualisation is a generic term primarily covering representations of numerical data. It has two main branches: statistical graphics and thematic cartography. Both deal with the visualisation of quantitative data but meet different aims. Statistical graphics refers to any field where a range of graphical methods can be used for the purposes of statistical analysis. Cartography, on the other hand, deals with representations of spatial domains.

Visualisations can be either *static* or *dynamic*. The former tend to be pictorial and are useful as learning aids and *aides-memoires*. The latter can be used to track fluctuating information, thereby assisting humans in their understanding of dynamic information.

450 http://www.vrvis.at/TR/2002/TR_VRVis_2002_041_Full.pdf
451 Professor Andrew Hanson of **Indiana University**, USA, is involved in research into scientific visualisations, in particular virtual astronomy. http://www.cs.indiana.edu/%7Ehanson/



Tantrum

Methods of Visualisation: History

The graphic representation of quantitative information has a long history. Its origins are closely related to those of thematic cartography, statistical graphics and data visualisation. Thematic maps differ from standard reference maps in that they are used to display the spatial distribution of one or more geographic attributes or variables rather than the location of *spatial* phenomena.[452] The process has been strongly influenced by the development of statistics in the 19th century as well as technological progress in the 20th and 21st centuries.

The earliest examples of data visualisation can be found in the making of maps and diagrams for navigation and exploration, notably the celebrated planetary movement diagram of 950AD. Johann Gutenberg's invention of the printing press in 1453 opened up huge possibilities for the visual presentation of text and graphics.

By the 16th century, methods and instruments for accurate observation and measurement of physical phenomena had been developed, including the use of rectangular coordinates, trigonometric tables, the camera obscura and pendulum properties. The following century saw the birth of probability theory (Blaise Pascal, Christian Huygens), the appearance of new disciplines such as analytic geometry (Pierre Fermat, René Descartes) and the theory of errors in measurements, all of which formed the bases for the development of novel visualisation techniques. The same epoch saw the rise of demographic statistics and its application to problems associated with political and social sciences. The regular collection of empirical data regarding human populations began in the 18th and 19th centuries and the importance of these datasets for governmental and societal planning began to be recognised.

This 'golden era' in the development of statistics was accompanied by a rise in visual thinking: diagrams were used to illustrate mathematical quantities; *nomograms* were developed to aid calculations [453] and many new graphic forms were invented to make the properties of empirical numbers, such as their trends and distributions, more easily communicable and available for visual inspection.

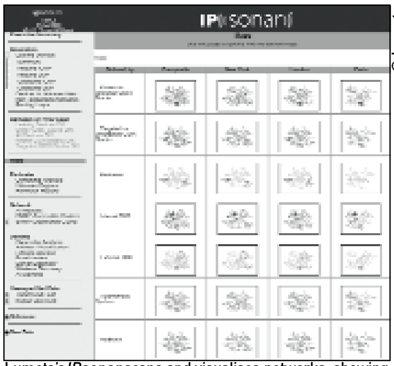
The first maps were hand-drawn. Later they were etched on copper plate and

452 http://go.owu.edu/~jbkrygie/krygier_html/geog_353/geog_353_lo/geog_353_lo02.html
453 A nomogram is a graphical representation of numerical relations.

coloured manually. Later still, lithography, photo-processing and dedicated computer softwares were used but visualisation-makers have always had to overcome the limitations of the available technology. Recent advances in statistical computation and graphic display have provided tools for data visualisation that would have been unimaginable fifty years ago. Concurrent advances in human-computer interaction have resulted in completely new forms for the dynamic investigation of graphic information with increasingly flexible control for the user. There have been considerable advances in information visualisation in general, particularly for the computer-assisted display of graphs, networks, hierarchies, databases and text, where the handling of large-scale datasets continues to pose challenges.[454]

Where and How Data Visualisation is Currently Used

Contemporary developments in computer processor technology have led to a vast increase in the amounts of data that are generated and processed. Data visualisation, as a logical outcome, has developed as a key technology for accessing, exploring and analysing these enormous new datasets. Visualisations have practical applications in almost every field of endeavour, including medicine, meteorology, economics, engineering and the military.[455] Some typical applications of data visualisation are outlined below.



© Lumeta

Lumeta's *IPsonar* scans and visualises networks, showing access points, connections and leaks

Financial Data and Business Intelligence

The uses of data visualisation techniques in the finance sector are widespread and it is perhaps in this area that visualisation has its most obvious and measurable benefits. Portfolio management, with the rapid fluctuation of stock and share prices, is a common example of dynamic visualisation at work. Most readers will be familiar with the variable graphs and charts used to track the progress of financial markets over the course of a day, a week, or a decade. The ability to review, contextualise and evaluate financial parameters quickly is another advantage provided by visualisation, improving the quality and speed of decision-making.

Business Intelligence (BI) provides organisations with a means of improving business activities and decisions, facilitating contacts with their customers and adapting to changing market conditions. BI uses a number of technologies and methods for the collection and analysis of data including data processing, data warehousing, data mining and harvesting, database query and reporting, analysis of shared multidimensional information, and data visualisation.[456] Visualisation software tools improve and speed up decision-making by reducing the chance of error. They may also assist in identifying trends, problems and

454 See the Human Computer Interaction Lab at the **University of Maryland**, USA, for more on the visualisation of very large datasets. http://www.cs.umd.edu/hcil/millionvis/

455 Visualisation applications are often combined with GIS and virtual reality in military planning and intelligence, operation rehearsals and battle simulations.

456 Database entity-relationship (E-R) diagrams are a good example of practical visualisation for design.

tendencies faster, generating improved returns on investments (ROI).

Conventional visualisation techniques return static images to user queries but contemporary methods communicate directly with databases to represent information with interactive 3D images that may reveal hidden patterns and trends in real time.[457] Scorecards and dashboards are often used to interpret data in a general business context.[458] These are simple desktop or Web applications providing a defined set of key metrics to obtain a quick evaluation of a project or process status.[459]

Geographic Information Systems (GIS)

An easy way to evaluate certain information is to visualise it on a map. GIS technology makes available intelligent digital maps that process information in a much friendlier and more effective way. This is a good example of how geography can be applied to extract information and make decisions.[460] Relating locations and information is a process that can be used for a range of purposes in all sectors, from business to government planning, the military, the community and the education sector. The **European Space Agency**'s *EnviView* gateway has been introduced to facilitate the visualisation of satellite information, allowing users to access complex geophysical data in their preferred mode.[461]

Choosing a particular place, planning a marketing initiative, selecting a neighbourhood, allocating assets, exploring archaeological movements or responding to emergencies – each of these problems is related to geography and each can be assisted by the visual presentation of data in a clear and comprehensible context.

Project Planning

Data visualisation techniques are widely used for management of projects. There are a lot of commercial software applications which monitor the duration of various project events, their relationship and interdependencies. Different graphic diagrams are available in order to illustrate various project characteristics, inconsistencies and delays.

Visualisation can also assist in security issues. In his paper 'The Spinning Cube of Potential Doom,' Stephen Lau shows how three-dimensional visualisations can be used to track malicious or suspicious Internet traffic in much the same way as air-traffic controllers track aircraft.[462]

Medicine

Data visualisation tools are used widely in medicine. Treatment planning systems combine the actual physical data from a patient with computer-generated graphics replicating their anatomy. Data visualisation techniques assist with telemedicine whereby examinations and consultations are remotely performed, cutting costs and bringing expertise into

457 See http://www.unifiedfield.com for examples of 4D dynamic data visualisation for the finance sector.
458 A *dashboard* is a graphical user interface (GUI), often resembling the dashboard of a car. These can convey information from multiple sources in a single interface.
459 http://www.bridgefieldgroup.com/glos2.htm
460 See the section on Location-Based Systems, above, for much more on GIS and its applications.
461 http://esapub.esrin.esa.it/eoq/eoq68/EnviView_68.pdf
462 http://www.nersc.gov/nusers/security/TheSpinningCube.php

distant or isolated areas. This includes telesurgery by which surgeons can perform operations on patients remotely[463] Similarly, in human and veterinary medicine visual simulation tools are used by students to practice techniques without risk to patients.

Future Trends

The ever-growing variety of visualisation applications highlights the range of ways this technology can help us access and process information more effectively. But this does not mean that all these applications will soon be in common use. Many visualisation techniques are created with a specific purpose in mind and, as such, are optimised to operate with particular types of data. To make them work with other data types would require significant modification. Other applications use complex databases that can be expensive and time-consuming to create and maintain. For this reason, the fruits of visualisation cannot simply be listed in terms of the applications it makes possible.

A number of advanced scientific projects have evolved into commercially available products. This trend can be illustrated, for example, by the availability of numerous software visualisation products for the **Visible Human Project** that aims to create complete 3D representations of male and female human bodies.[464] These include the **NPAC/OLDA** *Visible Human Viewer* – a Java applet tool, which allows users to select and view 2D slices of bodies. This work incorporates research on dynamic query visualisation carried out by the **University of Maryland** that developed *Spotfire* software to provide business decision-makers with interactive visual analytics. [465] **Xerox** has created a dedicated company called **Inxight** in order to market products such as *SmartDiscover, VizServer,* and *Inxight Software Development Kits*.[466] Similarly, **Lucent Technologies** has founded subsidiary companies **Visual Insights** and **Advizors Solutions** in order to sell software products arising from its system of visualising software code.[467]

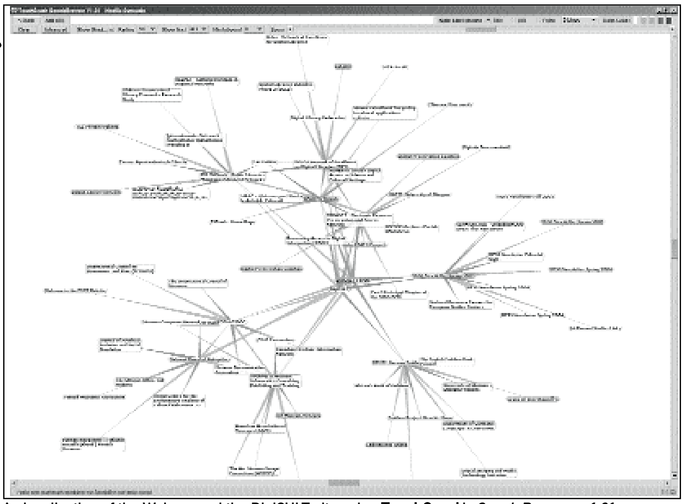
The increasing number of commercial visualisation applications indicates that there is a potential market for systems that incorporate visualisation. As an illustration of this process, we now present a few examples where the full potential of advanced visualisation techniques can be seen.

- **Balanced Scorecards** are management techniques based on measurement, visualisation and analysis of specific processes which provide decision-makers with business intelligence (BI) capabilities, i.e. with means to examine the outcomes of these processes and to take consequential measures;[468]
- **Digital Dashboards** are graphic representations containing sets of indicators providing access to key business information. Many vendors offer such advanced interfaces, including **McCracken Design, Infommersion, Corda, Principa, Visual Mining, Compaq** and **IBM**.[469] Microsoft offers a customised *Office*-based solution

463 See the section on Telepresence, Haptics and Robotics, above, for more on telemedicine.
464 http://www.nlm.nih.gov/research/visible/visible_human.html
465 Spotfire became a company in its own right in 1996 http://www.spotfire.com/about/spotfireexperience.asp
466 http://www.inxight.com/
467 http://www.visualinsights.com/; http://www.ADVIZORSolutions.com
468 A list of Balanced Scorecard products, services and providers can be found at http://www.balancedscorecard.org/consult/vendors.html
469 http://www.mccrackendesign.com/application.html; http://www.infomersion.com/; http://www.corda.com/; http://www.principa.net/software/digitaldash.php; http://www.visualmining.com/products/index.html; http://www.compaq.com; http://www.ibm.com

as a complement to the Shared Point Portal;[470]

- The **Enterprise Information Portal** is a customised and personalised Web-based interface for corporate intranets, which allows access to a variety of internal and external e-Business and e-Commerce applications, databases, software tools, and services;[471]
- **Lookmarks** are thumbnails of existing Web pages that can be visually arranged within a 2.5D space, just as papers can be placed on a desk.[472] The system can be implemented in Java and Java3D. It provides users an opportunity to structure and manage separate Web pages within a multidimensional space.



A visualisation of the Web around the DigiCULT site using **TouchGraph**'s *GoogleBrowser v1.01*

How Visualisation Works

Visualisation Techniques

A number of simple visualisation techniques will already be familiar to the majority of this report's readers, especially those familiar with spreadsheet packages. Examples include *graphs, charts, plots, maps* and *still and moving images*.

Graphs display the relationships between variables graphically and are cast along axes usually labelled x, y, and z. They are especially useful in showing the broader trends in data.[473] Charts provide a variety of ways of displaying information graphically. Pie charts and bar charts are the most common examples.[474]

Maps are abstract representations of the physical features of, say, a portion of the Earth's surface generally displayed graphically on a planar surface. Maps display signs and symbols as well as spatial relationships among the features. Typically, they emphasise, gen-

470 http://www.microsoft.com/technet/prodtechnol/sppt/sharepoint/reskit/part5/c23spprk.mspx
471 http://highered.mcgraw-hill.com/sites/0072440783/student_view0/chapter3/glossary.html
A list of corresponding software products and providers can be found at:
http://www.capterra.com/enterprise-information-portals-solutions
472 http://www.ims.tuwien.ac.at/publication_detail.php?ims_id=26
473 http://www.ncsu.edu/labwrite/res/res-glossary.html
474 See the Appendix, below, for a longer list of chart types.

eralise and omit certain features from the display to meet design objectives.[475] Plots are charts or maps tracking the movements or progress of an object.[476] The primary use of these schematic drawings is in showing how objects are constructed, or how they work.

Still images can also be used to present information graphically. Potential uses include history, where many factors can be expressed simultaneously using a single well-chosen image or diagram. Animated images are often popular as they can present the dynamics of development of a certain object or groups of objects.

Visualisation Tools

Basic data visualisation tools are widespread nowadays. Popular software applications such as *Word, Excel, Quattro Pro*, and *PowerPoint* require only basic data visualisation skills for the user to obtain impressive results. For more sophisticated users, specialist tools provide a variety of methods for studying data and presenting the results in a readily understandable way. These tools and their uses depend strongly on the application field. In archaeology, for example, the most common visualisation tools are *ArcView, Excel*, and *Quattro Pro*.[477] In economics, a number of visualisation tools are used for visualisation data in a variety of graphs including *Microfit, Minitab*, and *LIMDEP*. A wider range of visualisation tools are used in geography, the most popular being a range of GIS software rarely used in other subject areas, e.g. *MapInfo, ArcView, ArcInfo, IDRISI*. In sociology and social policy, visualisation tools such as *PowerPoint* and *Harvard Graphics* are used to present statistical data through the use of simple graphs. In the social statistics, *Minitab* tends to be the visualisation tool of choice. The most widely used visualisation tools are summarised in the table below:

Application area	**Software tool**
Spreadsheet software	**Microsoft** Excel, Quattro Pro
Presentations software	**Microsoft** PowerPoint, TurboDemo, Keynote
Graphic packages	3DStudio Max, Artworks, AutoCAD, Claris Works, Corel Draw, D-prime Beta, Freelance, GLIM, GSharp, Harvard Graphics, Common Lisp, **Microsoft** Drawings, Popeoream, Surfacer, Tolis123, Toolbook
Statistical software	ExperStat, LIMDEP, Matlab, Microfit, Minitab, SAS, Schema, SECOS, SigmaStat, SPLUS, SPSS, Statview, XLISP-STAT
Image processing software	Adobe Illustrator, Adobe *Photoshop*, ASAP, Corel Xara, Ghostview, Image Prep, Imagetool, LView Pro, Micrographx, Paintshop Pro
GIS software	ArcInfo, ARCVIEW, CDV (Cartographic Data Visualiser), ERDAS Imagine, GIMMS, IDRISI, MapInfo, MapMaker
WWW software	Numerous standard software tools (included in all operating systems) for displaying static images (GIFs, animated GIFs, and JPGs), video (AVI and MPEG formats), and other technologies such as Java, VRML.

475 http://www.mcag.cog.ca.us/gis/glossary.htm
476 http://www.cogsci.princeton.edu/cgi-bin/webwn
477 Ell, P. 'A Survey of Visualisation Tools in the Social Sciences,' available online at http://www.agocg.ac.uk/reports/visual/survey/visurvey.pdf

Thinkmap Inc, a leading visualisation technology company, recently launched a new release of its flagship technology, also called *Thinkmap*.[478] The *Thinkmap SDK* (v.2.5) provides visualisation solutions for standard applications. It works with various data sources (XML, SQL, and Flat File Data) and can present numerous views of the same data simultaneously, incorporating multiple data sources into one visual interface. Several pre-configured visualisations are available and a library of interface elements is provided to assist developers and Web administrators. *Thinkmap* tools enable users to create customised applications with their own data and to integrate them with corresponding enterprise applications.

KartOO is a meta-search engine with visual display interfaces.[479] When a search procedure is performed, the program launches the query to a set of search engines, collects and compiles the results and represents them as a set of interactive maps using a proprietary algorithm and *FlashPlayer*. An HTML version with results in the form of classic lists is also available.

The Four Stages of Visualisation

There are four primary stages to creating visualisations: (I) data input; (II) data filtering; (III) data mapping; and (IV) data rendering. The data input phase concerns the collection and storage of data and is performed independently of any visualisation technique. Data acquisition can be performed by means of standard input devices (keyboard, mouse, light pen or joystick) by importing data from existing sources (scanners, cameras, video equipment) or peripheral devices (magnetic tapes, hard disk drives, CDs), by acquiring data from standard measurement devices or dedicated experimental installations, or simply by simulating them numerically using appropriate software packages.

Filtering is the technique by which an application will display only those data that meet particular criteria. This form of pre-processing converts data into comprehensive form and ensures that display algorithms work satisfactorily, allowing users to produce different views of the data without actually affecting the raw information. Filtering techniques can significantly increase the effectiveness of data entry screens. Identifying specific patterns in input data can considerably reduce the amount of work required to locate a given piece of information. Typical filtering procedures include:

- *format conversion* (adapting data format for further visualisation stages);
- *elimination* of incorrect, invalid or unknown data;
- *redefinition of variables* thus reducing the complexity or the number of possible values by means of such techniques as smoothing (where excessive data values are not taken into consideration);
- *clamping* (where data values are limited to a certain range of values);
- *interpolation* (where the unknown data values are estimated based on known surrounding values); and
- *rounding, clustering and magnitude calculation/normalisation* (where data are scaled to a particular value).

All filtering procedures are performed by dedicated software packages.

478 http://www.thinkmap.com/
479 http://www.kartoo.com/

The data mapping stage involves the transformation of data into different representative form(s). This is the stage at which data values and attributes are matched to graphic entities and attributes using specific software programs. Popular applications include:

- *ArcView*, a complete desktop GIS solution[480] and one of the leading packages for the mapping and analysis of all types of spatial data;
- **MapInfo Professional**, a set of packages, including *MapX* that embeds mapping functionality into new or existing applications, and *MapXtreme* Java edition, a Java-based Internet mapping server for broad deployment of mapping applications;[481]
- The *Mapland* spreadsheet mapping software;[482]
- *ExpertGPS* from **OziExplorer** mapping software for Garmin, Magellan, and Lowrance GPS users;[483]
- **Golden Software**'s *Strater, Surfer, Grapher, MapViewer* and *Didger*, which comprise a whole set of advanced mapping and graphing solutions.[484]

Data rendering is the final stage in the process, involving the calculation of image details and their display, sometimes requiring dedicated display hardware and software. Hardware devices typically used for data rendering are graphics accelerators and video boards which can capture video data from cameras, process it, add visual effects and reformulate it into a video stream. There are a number of commercially available software packages for data rendering, including:

- *3Di*, an open GL-based rendering technology that enables users working in a standard Web browser to process and add images and textures to photographic images;[485]
- *AccuRender*, a photorealistic rendering add-on for AutoCAD;[486]
- **Adobe** *Photoshop, Illustrator*, and Web tools such as *Atmosphere* for creating realistic and immersive environments online;[487]
- **Eovia**'s *Carrara Studio*, a graphics application for Macintosh and *Windows* that handles 3D modelling, animation, rendering and special effects;[488]
- *formZ*, a 3D solid modelling, visualisation and rendering software;[489]
- **Alias**'s *ImageStudio* rendering software, which transforms 3D models into visuals;[490]
- **LightWork Design** supply rendering, simulation and visualisation software, including *LightWorks*, a rendering tool for producing photorealistic 3D images and animations, the *LightWorks Real-time Plus* add-on for interactive rendering, and *LightWorks Sketch*, a rendering product that provides the ability to instantly create non-photorealistic, impressionistic and stylised design renderings;[491]
- **Okino Computer Graphics**, whose applications include the *NuGraf Rendering System* (photorealistic rendering software), the *PolyTrans* 3D model translation software and *NuGraf Developer's 3D Toolkit*, 3D photorealistic component libraries for software developers;[492]

480 http://www.esri.com/
481 http://www.mapinfo.com/
482 http://www.softill.com/
483 http://www.oziexplorer.com/
484 http://www.golden.com/
485 http://www.cre8tiv.com
486 http://www.accurender.com
487 http://www.adobe.com/products
488 http://www.eovia.com
489 http://www.formz.com
490 http://www.alias.com
491 http://www.lightworks.com
492 http://www.okino.com

- **Digital Immersion Software**'s *Presenter 3D* which provides photorealistic rendering, animation, presentation and publishing tools for visual product communication;[493]
- *TrueSpace* from **CADopia** which allows users to create 3D models, photorealistic renderings and key frame animations;[494]
- *ZBrush* from **Pixologic Inc** renders 3D geometry, materials and textures in real-time without the need for graphic accelerators.[495]

Visualisation Applications

The development of data visualisations has produced a variety of applications which can be classified according to different criteria including the type and range of user tasks required (i.e. whether this must be interactive or simply illustrative), the type of data being visualised and the attributes to be used to represent the data (e.g. colour, size, shape, proximity, and motion).

In interactive systems, visualisation is sometimes used to reveal the characteristics of a dataset. Users do not usually have a full understanding of the data and they use the visualisation to investigate different characteristics. In such cases, speed and simplicity are fundamental requirements for the process though more complicated visualisation options may be necessary for complex data.[496] A common practice in using visualisation for data exploration is to acquire a qualitative overview to reveal patterns, trends and relationships. This overview may then be used to conduct more focused exploration for quantitative analysis. Exploratory data visualisation can be especially helpful for discovering errors or inconsistencies in a dataset.

Once a clear understanding of the data has been gained, visualisation can be used as a presentational tool. An old maxim says that a picture is worth a thousand words, but it is also true that a badly designed presentation may take a thousand words to explain. This is why a successful visual representation of complex data needs to be effective, accurate, efficient and aesthetic. Information must be presented in a clear, unambiguous form easily interpretable by the anticipated users. Proportions should be consistent so that the visualisation does not give a misleading impression of the underlying data. It is also important to exclude irrelevant details that may cause more confusion than enlightenment.

Aesthetics calls for visualisations that do not disturb viewers' senses, i.e. graphics with appropriate colours, neat lines, and a fine sense of proportion.[497] Depending on the *perception attributes* (such as colour, size, shape, proximity, and motion) used to represent data, applications can be further classified as follows:[498]

493 http://www.presenter3D.com
494 http://www.cadopia.com/products/products.asp
495 http://www.pixologic.com
496 Very complex data (and data relations) can lead to very complex visualisations. See Bergmann, J., M. Paier and A. Resetarits (2003) 'Towards a Roadmap of Complexity Research Using a Bibliometric Visualisation Tool' for some literature-based examples.
497 It is important to take potential access issues in to account, such as colour blindness. Many guidelines exist to assist designers in this task. For example, http://builder.com.com/5100-6371_14-5112995.html
498 Of course, part of the power of visualisation arises from the combination of these techniques.

Spatial attributes

A visualisation's spatial attributes represent the most basic way of carrying information. Data are often spatially located. Three-dimensional representations are almost always flattened to two-dimensions for display on standard computer screens and printed media. This means that additional perceptual characteristics must be used to convey depth information. For static images, these will include lighting, perspective, and *occlusion* – a visual obstruction whereby an opaque surface prevents another surface from being seen. For moving images, the ability to change the viewpoint of the projected image (known as *parallax*) is a powerful perceptual cue that provides a stronger sense of depth.

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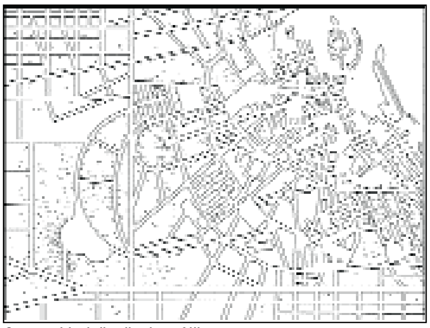


Geographical distribution of library users

Elements that can be plotted spatially are points, lines, surfaces and volumetric data, each of which has standard techniques for visualisation. In 2D, point data has a unique position with respect to the axes but in 3D-representations additional information is required to give a sense of depth. In a static image, this information can be supplied by placing the point on a surface or by using drop lines (also known as stem plots). Drop lines can also be used when plotting lines although, in the case of 3D representations, it is advisable to give the models a definite physical form. The use of dashed lines considerably increases the complexity of the visualisation. It is recommended that the number of lines on a plot be kept to a minimum and multiple plots are used especially when parameters with different physical units are on display. In this way the use of legends can be avoided. They are usually provided in visualisation packages but rarely add to overall clarity.

Displaying surface data is more demanding since they have as many dimensions as the display surface. Techniques used include elevated surfaces or contour plots with or without depth cues for lighting and/or transparency. Volumetric data can cause even more problems for plotting on two-dimensional displays. The basic techniques for visualising such data are reducing the spatial dimensions by working with two-dimensional slices through the data, plotting isosurfaces, and volumetric rendering.[499]

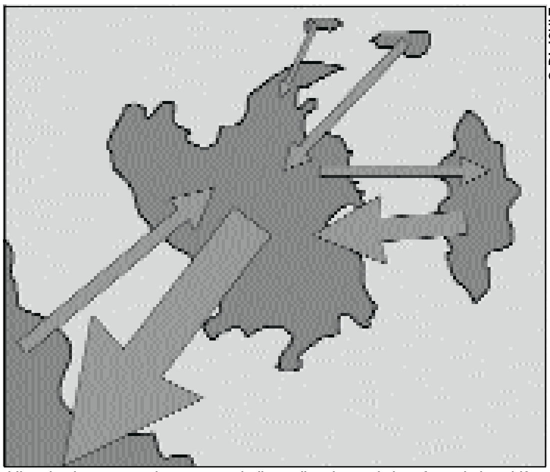
Colour attributes

Colour is one of the most widely used perceptual attributes for visualisation. Properties such as hue or saturation are used for this purpose. Visualisations almost always use colour as a singular perceptual dimension since it is extremely difficult to separate multiple pieces of information that are encoded into colour. The use of colour normally requires a legend providing quantitative information.

499 Isosurfaces are surfaces within a volume that have the same parameter value. Volumetric rendering outputs a 2D dataset on a standard plane.

Glyphs

Glyphs are discrete objects whose properties can be used as visualisation attributes. Such objects can include lines/arrows giving the direction and magnitude of vector quantities, small broken ellipses, and flow lines. As with colour, legends are normally used to give a quantitative understanding of glyph values.



Migration between regions: arrows indicate direction and size of population shifts

Time

Time can be used as a visualisation dimension by changing the parameters of the visualisation at each time step or enabling the user to vary the time point interactively. Such animations can be particularly effective where time is a key data characteristic and is an intrinsic factor in dynamic visualisations.

Visualisation and Data Types

Another basic method for classifying visualisation applications is by *data type*. This classification recognises seven data types: one-dimensional, two-dimensional, three-dimensional, multi-dimensional, temporal, hierarchical, and network.[500]

One-dimensional data

One-dimensional data comprise simple, linear information such as texts or lists. The usefulness of visualising such data will depend on two key factors: the size of the dataset and the tasks required of it. The most general form of one-dimensional data is a text document. Although rare, there are cases when the user may wish to take advantage of the possibilities offered by computers in visualising the relationships between various parts of a document.[501] Visual filters such as highlighting, zooms and changes in colour can be used to reveal patterns and structures. Other potentially useful features comprise discreet displays of footnotes and fast navigation within a large amount of text. All these applications show that even for simple, one-dimensional data, visualisation can facilitate the manipulation of information.

500 Shneiderman, B. (1998) *Information Visualisation*, Designing the User Interface: Strategies for Effective Human-Computer Interaction (Third ed., pp. 522-541). Reading, MA: Addison Wesley Longman, Inc.

501 This is especially true in hyperspace, where the relationships between parts of a document may be both multi-dimensional and (thanks to XML) multivalent.

Two-dimensional data

Two-dimensional data are used to represent the position of an item in space. Measured on x- and y-axes, width and height characterise the size of an item. Two-dimensional data visualisation is commonly found in GIS deployments. Large commercial GIS systems have long been used for planning, management, weather forecasting, and mapping. Simple GIS applications are a familiar sight on the Web: customised maps display the location and features of a particular set of geographical coordinates in response to user queries.[502]

The traditional geographic map is an excellent example of how large amounts of data can be displayed visually and efficiently. During a cholera epidemic in London in 1854, Dr John Snow plotted the location of deaths on a map, which revealed a concentration of victims near a particular water pump. The water pump was found to be contaminated and removed from service, preventing further infection.[503] Today, statistical information is often plotted on maps and is used in geography, planning and many other disciplines.

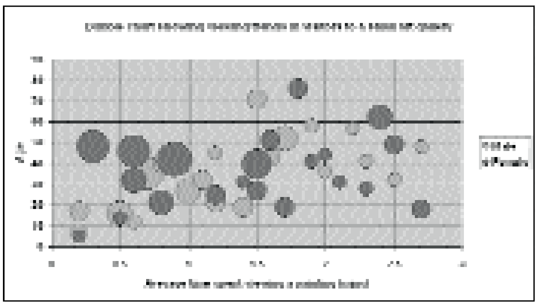
Three-dimensional data

Two-dimensional data becomes three-dimensional by adding *volume* properties. Many applications in scientific visualisation are three-dimensional since a primary purpose of scientific visualisation is to represent real, three-dimensional objects. These computer models have provided scientists with a means of performing manipulations and tests in order to forecast how objects are likely to behave, tests which may be too expensive, too dangerous or too difficult to carry out on real objects.[504]

3D visualisation has been applied to a wide variety of areas, especially architectural, archaeological and medical applications. Virtual reality technologies and digital imaging are used to create systems that represent three-dimensional data realistically. These systems provide a means to examine and explore 3D objects and spaces in ways more convenient and efficient than may be possible in reality. 3D models and animations are now used to complement (and even replace) the maps, photographs and charts conventionally used to communicate this kind of information.

Multi-dimensional data

Multi-dimensional data describes an item with more than three attributes, each of which is given more or less equal prominence in the visualised context. Multi-dimensional visualisations are commonly achieved by mapping differ-



This example of a bubble chart shows four types of data for gallery visitors.

502 Data visualisation is a very good way of imparting information regarding climate conditions – the Geophysical Fluid Dynamics Laboratory has an excellent Web page featuring demonstrations of such work. http://www.gfdl.noaa.gov/products/vis/gallery/

503 Tufte, E.R. (1983) *The Visual Display of Quantitative Information*. Cheshire, Connecticut: Graphics Press.

504 See the **American Museum of Natural History** for examples including visualisations of the respective skull sizes of male and female baboons. http://research.amnh.org/mif/scivizgallery/galleries.html

ent types of quantitative data to visually distinguishable attributes. Existing techniques produce results that are adequate for specific data analysis but generic use tends to produce less satisfactory results across a broader general scale.

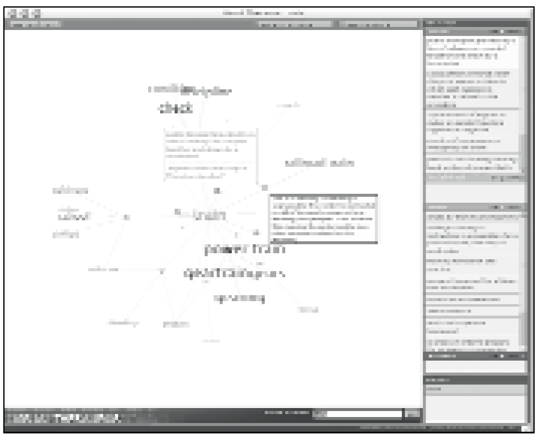
Temporal data

The graphical display of data over time is one of the most widespread and powerful techniques of visualising information and has been practiced for more than two centuries.[505] In recent years, the timeline has been applied as a basis for presenting data in commercial software applications such as **Microsoft**'s *Project*. This allows project managers to observe the date and duration of events and their relationship to each other, highlighting events that depend on one another.[506] The timelines in multimedia authoring programs (such as **Macromedia**'s *Director* and *Flash*, and **Adobe**'s *Premiere*) provide a way for users to synchronise events.[507] While text-based interfaces can also be used for such tasks, the visualisation provided by a timeline is a more intuitive way of working and provides an overall view of events that would be difficult to communicate through text alone. When temporal data are less abstract it can be represented in more direct ways, for instance via three-dimensional simulations.

Hierarchical data

Hierarchical (or tree) structures are common in all types of information organisation. Business organisations, computer data storage systems and genealogical trees are all examples of hierarchical data organised in a tree structure. Visualisations of these structures are equally widespread. The *Windows Explorer* interface displays the directory structure of a computer visually, enabling users to more quickly understand how data are organised than likely with old-fashioned text-based command-line interfaces and simplifying navigation to a particular folder or file. Tables of contents and site maps are often found on Web sites to assist users navigating them. In large hierarchical structures, some styles of tree-view used by file management programs may be unable to represent entire structures in a single view. When nodes are collapsed to overcome this, they may become invisible. Otherwise, the user can be reduced to scrolling several computer screens to view all of the information. One way of solving this problem is to represent large hierarchies in three-dimensional space. This has the additional advantage of modelling multivalent dependencies and relationships, as with network data, below.

© Thinkmap



The Visual Thesaurus takes a unique, and remarkably beautiful, approach to presenting the results of a word lookup.

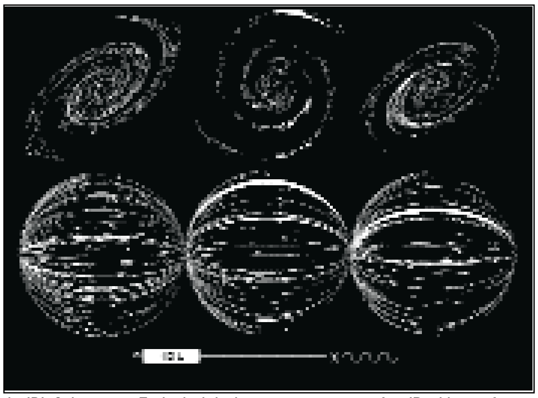
505 Tufte, E.R. (1983) *The Visual Display of Quantitative Information*. Cheshire, Connecticut: Graphics Press.
506 http://office.microsoft.com/project/
507 http://www.macromedia.com/software/director/; http://www.macromedia.com/software/flash/; http://www.adobe.com/products/premiere/

Two good examples of this technique are the *Visual Thesaurus* and the Global Network of Dreams (GNOD).[508] The *Visual Thesaurus* is a learning tool where words are displayed in a 3D space similar to the way we think of and associate words and their meanings. GNOD is a search engine dedicated mostly to music, books and movies and search results are displayed in a 3D space. This has the additional advantage of being able to model multivalent dependencies and relationships, as with network data, below.

Network data

Network data usually have relationships (or links) to a number of other items. Since the attributes and relationships between items can be very complex, network data are very difficult to convey with methods *other than* visualisation. Attempting to understand Internet traffic patterns, for example, with their peaks and valleys of usage and alternate paths between nodes would be more difficult using only tables and statistics. The task is made much simpler by visual representations of these complex data.

Graphic network maps have been used for many years in enterprise-level commercial network management products. Network managers use these graphic interfaces to monitor an enterprise's computer network and access software functions to troubleshoot network problems. Network visualisations can also be used for types of network data unrelated to computer networks such as the interconnected components of (object-oriented) software code.



© IDL.net

An IDL Galaxy map: Each pixel dot is a one-to-one map of an IP address of cyberspace, and colour coded according to domain type.

Visualisation and the Heritage Sector

Introduction

Possible applications of data visualisation in the heritage sector fit into two groups: improvements in information presentation and user analysis. In the first case, data visualisation can make different viewpoints on collections clearer to users, particularly the distribution of objects in various groups and the presentation over time of the dynamics of collection items. These processes can be deployed using interactive kiosks and displays as an integral part of an institution's in-house visual presentation. Alternatively, Web-ready visualisation techniques such as *Flash* and *Shockwave* can increase the virtual outreach of the site. Virtual collections can be compiled with the help of virtual reality (VR) and the three technologies, VR,

508 http://www.visualthesaurus.com/; http://www. gnod.net

visualisation and GIS, can be combined in impressive multimedia presentations.[509]

For reference works, **ThinkMap Inc**'s *Visual Thesaurus* presents an innovative, animated interface for exploring the connections and relationships between words.[510] Similarly, **GNOD** visualises metadata submitted by Web visitors, showing similarities between musical groups, allowing users to gauge the likelihood of enjoying the work of certain bands.[511] Similarly, **Whichbook.net** lets users choose the kinds of books they want using categories on a sliding scale.[512] For example, a query with the sliders set towards *funny, unusual*, and *short* returns poetry by Paul Muldoon and fiction by Will Self together with more famous parallels for contextualisation. Inverting the sliders returns Joanna Trollope and Ahdaf Soueif.

For the collection and analysis of user data, visualisation tools can assist management study and present key factors about collections and user interests. In addition, special techniques can be applied for visually-impaired users. For information retrieval, data visualisation can help users contextualise the frequently large search results returned by search engines. KartOO groups query results on a map with links between related sites.[513] **Mooter** provides a similar service, clustering search results by meaning.[514]

The **Texas Memorial Museum**[515] in Austin, Texas uses *VRCO Full Circle, Museum Edition*, a visualisation system comprising immersive 3D display and dedicated software which allow models and information from various sources to be virtually exhibited.[516] This ability to present museum materials in new ways that provide both entertainment and education will be of great interest for heritage institutions as they compete with other leisure time activities for the attentions and imaginations of their audiences.

The world's great museums are using self-service technologies in order to improve public access to their exhibits. Rotterdam's **Museum Boijmans Van Beuningen** uses gestures to interact with a Data Wall, a giant interactive display providing access to all 117,000 pieces in the museum's collection ranging from prehistoric archaeology to modern art.[517] The New York's **Museum of Modern Art** is deploying public access kiosks, LCD screens and PDAs in its newly constructed building.[518]

Since 1999, the **Museum of Anthropology at the University of Denver** has used GIS technology for resource management.[519] Museum collections can be managed efficiently this way, the GIS working with standard relational database tools offering visualisation and spatial analysis processes that support fundamental museum research and education tasks. GIS is an important research tool used by archaeologists for preparing documentation and inventories of sites and excavations, by naturalists to examine flora and fauna, by scientists to model the results of climate

509 Two systems which use VR visualisation to benefit the cultural heritage sector in different ways are described in "Interfaces for digital libraries at CNAM (1993-2003)" in *DigiCULT.Info*, Issue 8, August 2004, pp. 26 and "Cistercians in Yorkshire: Creating a Virtual Heritage Learning Package" in *DigiCULT.Info*, Issue 6, December 2003, pp. 34 http://www.digicult.info/pages/newsletter.php

510 http://www.thinkmap.com/visualthesaurus.jsp

511 http://www.gnoosic.com/ Another site, **musicplasma**, provides a different interface for the same purpose, and links album covers and song titles to each artist, together with their estimated depth of influence.: http://www.musicplasma.com/

512 http://www.whichbook.net/index.jsp

513 http://www.kartoo.com/

514 http://www.mooter.com/

515 http://www.tmm.utexas.edu/index.html

516 http://www.vrco.com/fullcircle/museum_edition.html

517 www.boijmans.nl

518 http://www.moma.org/

519 http://www.du.edu/anthro/museum.htm

changes on global weather patterns and by earth scientists to illustrate field data.[520]

Case Studies

VICODI – Visual Contextualization of Digital Content[521]

Visual information retrieval systems play an increasingly significant role in the ways we access, analyse, and understand information. However, most such systems do not provide a combination of visual representation with contextualisation of the retrieved information. By definition, data taken out of context are pieces of *information*. Information structured in context with other *words* and *ideas* becomes *knowledge*. This progression was at the heart of the VICODI project, the main objective of which was the development of a methodology and tools for comprehensive structuring and graphic visualisation of context to facilitate creation of new knowledge.

The project was a collaborative endeavour between seven partners from six European countries: Financial Coordinator **Systran S.A.**, France, Scientific Coordinator **RIDemo**, Latvia, and partners **Salzburg Research Forschungsgesellschaft m.b.H**, Austria, **Forschungszentrum Informatik an der Universität Karlsruhe**, Germany, **Národní knihovna Ceské republiky** (the Czech National Library), the School of Historical Studies, **University of Newcastle upon Tyne**, and the School of History, **University of East Anglia** (UEA), both England.[522] The project ran for a period of twenty-four months, from September 2002 to August 2004, and had a budget of €1,666,169, of which €997,182 came from the EU.

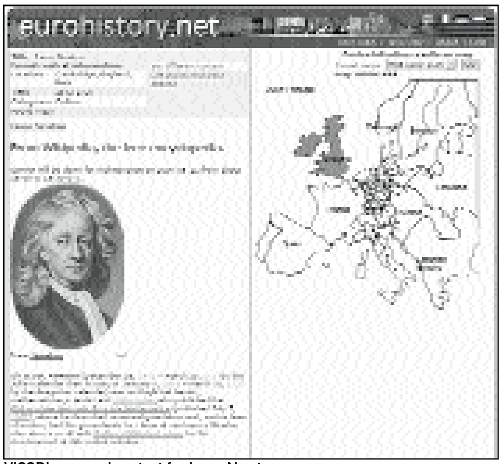
One of the project's main goals was the semi-automatic creation of contextual semantic metadata for digital resources. The context was visualised through historical maps and colour coded links, thus improving user understanding of resources. For their showcase domain, VICODI planners used European history from 500CE to the present. A Web portal (www.eurohistory.net) was developed which puts into practice the idea of contextualising historical resources like articles and images, and visualising their context. Context sensitivity is defined over topics, locations and time, and resources are retrieved via a context sensitive search engine which operates on multilingual input and a language-neutral ontology. Results are displayed through a graphic contextualisation interface based on *Scalable Vector Graphics* (SVG).[523]

© VICODI

The Eurohistory.net portal

520 http://www.esri.com/industries/archaeology/index.html
521 This case study was based on an email interview with VICODI's Richard Deswarte, Jan Oosthoek and Edvins Snore, conducted during September 2004. http://www.vicodi.org
522 http://www.systransoft.com/; http://www.ridemo.com/; http://www.salzburgresearch.at/; http://www.fzi.de/; http://www.nkp.cz/; http://historical-studies.ncl.ac.uk/index.asp; http://www.uea.ac.uk/his/
523 http://www.w3.org/Graphics/SVG/

© VICODI



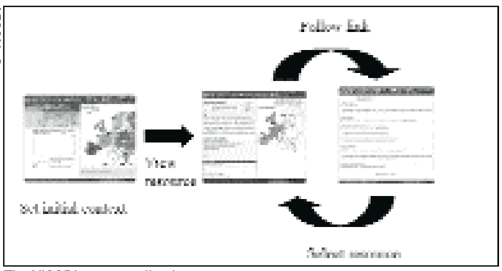
VICODI map and context for Isaac Newton

Most Internet graphics are in bitmap formats such as GIF, PNG or JPEG. Bitmap visualisations contain information on every pixel needed to display an image, making them large in size and consequently slower to download. Prior attempts to deliver high-quality, vector-based visualisations of dynamic data to the Web have had limited success, usually due to technical restrictions. However, the recent arrival of XML-based SVG now allows interface designers to concentrate more on content delivery and user interactions. The two main benefits that SVG images offer over conventional bitmaps are smaller file sizes and independent scalability, crucial within the Internet environment where download times must be minimised and where viewing platforms can differ dramatically. It is expected that most browsers will support SVG in the near future and, when this happens the market for SVG visualisation is likely to increase rapidly. The visual SVG components of VICODI's user interface were largely developed by **RIDemo**, with an independent SVG designer contracted on a temporary basis to help prepare the historical maps in co-ordination with a historian. Development of both the user interface and the SVG maps proved to be very time-consuming. All in all, it took two programmers the best part of two years to achieve. The SVG-based visualisation technique strives to work towards universal usability, supporting users with high- and low-spec setups equally. While long download times are a typical problem for most interactive geo-referenced visualisation solutions delivering vector-format maps, the SVG-based interface simplifies the visualisation task and cuts download times substantially.

The project has been successful in demonstrating the practicality and usefulness of a Semantic Web portal based on a newly-created historical ontology. Visualisation allows users to see at a glance the relevant location and period (important in the case of a history portal), and the colour coded/graded hyperlinks potentially provide an intuitive guide to additional resources.

The VICODI Contextualisation Environment addresses the management of search and retrieval as well as the management of information presentation, by (i) creating a cumulative and open knowledge space that can be enhanced by its users, and (ii) providing an innovative user interface employing SVG for presentation of historical information contextualised for location, time and subject. VICODI addresses two key technical aspects for next generation Semantic Web interfaces: (i) the need to provide contextualisation services for large knowledge spaces, and (ii) the development of more appropriate user interfaces for the visualisation of richly structured, contextualised content.

© VICODI



The VICODI contextualisation process

For evaluation, the VICODI system was made available on the Internet and a representative target audience of twenty-two professional historians, students and librarians was invited to test the prototype. The evaluators' initial response showed that the visual aspect greatly aids data presentation and that the maps provide a positive reinforcement tool for teaching purposes. It was said that the combination of maps and chronology offered a new way of searching that was potentially useful for pedagogical purposes.[524] Most testers found that the highlighted contextual links encouraged students to explore wider contexts and use more primary materials that helped show how primary sources relate to each other. This was regarded as the most significant feature of the portal. Some testers lamented the lack of detailed zoomable maps that would allow searches to be limited to national levels.

General evaluator opinion was that the Web portal contained a number of individual good ideas but the integration of elements was not as smooth as it could be. The map search was generally seen as a useful tool but the search facilities were considered cumbersome and complex and the integration of contextualised texts was thought to be poor.

With the benefit of hindsight, VICODI's developers feel that the combination of maps and colour coded hyperlinks as a means of visual contextualisation was perhaps too ambitious for a single project. While the project successfully showed that the system could work, the visualisation and contextualisation elements might have benefited from being developed in isolation and integrated once the independent systems worked better. Visualisation through hyperlinks proved possible but was server-intensive and slowed the system down.

The VICODI Web portal remains open to users although the developers stress that it is a prototype and not a fully-fledged working product.[525] In order to turn the current version into a more usable product, the design needs further development and refinement. In conclusion, VICODI has shown how a Semantic Web site based on a history ontology can function and contextualise search results with the help of visualisation techniques like maps and colour-coded hyperlinks. It demonstrates proof of principle by showing a working visual contextualisation Web application based on a history knowledge system. It enables Web users to visualise retrieved information, providing them with innovative tools for performing dynamic queries. Simplified input and rapid visual display of results enable more users to benefit from World Wide Web information, regardless of domain. The combination of maps, documents, images and, potentially, video provide a base for other cultural heritage projects to build on.

The Electronic Cultural Atlas Initiative[526]

The *Electronic Cultural Atlas Initiative* (ECAI) was established at the **University of California**, Berkeley in 1997, with a mission to improve international humanities scholarship through collaborative use of the digital environment, sharing data and placing particular emphasis on notions of time and location. In the words of ECAI directors Professor Michael Buckland and Professor Lewis Lancaster, the initiative aims to facilitate and encourage communication and information sharing between academic researchers, specifically those interested in the humanities and social sciences, and "the relationships between place, time, and topic in the study of culture and history".[527]

524 The system has since been developed to work with the Blackboard Learning system, http://www.blackboard.com/

525 http://www.eurohistory.net

526 This case study was based on information on the ECAI Web site: http://www.ecai.org, and on email correspondence between Professor Michael Buckland of the **University of California, Berkeley** and Martin Donnelly of DigiCULT. Secondary sources are given in footnotes.

527 Buckland, M. and L. Lancaster (2004) 'Combining Place, Time, and Topic: The Electronic Cultural Atlas Initiative' in *DLib Magazine*, May 2004. http://www.dlib.org/dlib/may04/buckland/05buckland.html

The initiative's linchpin is a *clearinghouse* of shared datasets, a database system accessible through a map-based interface providing dynamic visualisations of geo-temporally encoded data.[528] The metadata scheme is based on the *Dublin Core Metadata Initiative* (DCMI), with additional elements introduced to deal with spatial and temporal information. These make it possible to locate datasets in a variety of ways: visually, through a map-based interface or timeline, or textually by keyword or topic. A key advantage of the visual interface is the improved process for finding datasets in a variety of languages thereby encouraging and fostering improved international collaboration.

In the absence of existing software that met its aims, ECAI supported the development of the *TimeMap* application by two members of the Archaeological Computing Laboratory at the **University of Sydney**, Australia. *TimeMap* has two main components: a toolkit for creating projects and cataloguing datasets, *TMWin*, and the time/place visualisation tool, *TMJava*. *TimeMap* also provides a means of accessing remote datasets and mapping them to a consistent GIS format on local drives for further analysis with other compatible software packages. The software tools enable metadata editing, data upload and the creation of new user interfaces. When used in conjunction, *TimeMap* and the ECAI Metadata Clearinghouse allow users to find and download datasets that have been contributed by other researchers and then overlay them to create dynamic maps which can be visualised in different ways. In common with GIS systems, layers can be activated and deactivated. Then, dedicated time-bars allow the comparison of datasets from different periods. Users can make the most of GIS-style functions in creating their own base maps, potentially producing data with latitude and longitude attributes or using place names to identify locations. Problems arise when place names differ between languages (e.g. Rome, Roma) and when different scripts are used to create the datasets. In order to enable the display and comparison of datasets, records representing objects or events must first be identified in terms of time and location. This process, known as *geo-referencing*, overcomes one of the main problems when using Library of Congress Subject Headings: their inflexibility. If a researcher is interested in a specific geographical region rather than a political unit, it can be difficult to restrict searches to a narrow area. Political areas also change over time, developments that LoCSH has difficulty in reflecting. Gazetteers – tools for 'disambiguating' place names with the same name – are crucial to the ECAI's work in this area and the *TimeMap* software demands the explicit linkage of place names with geographical coordinates. Similarly, *time period directories* are an exciting development which may soon allow the use of timelines to track place name and boundary changes over periods of years, helping to contextualise changes more quickly than would be possible using flat, textual data.[529]

The ECAI project 'Going Places in the Catalog: Improved Geographical Access' explores the potential benefits of matching online catalogues with gazetteers, timelines and maps.[530] Clicking on pre-determined areas or drawing new boundaries allows users to define their own areas of interest. The coordinates of these areas can then be used to query a gazetteer thereby identifying without ambiguity the place names situated in or around the area. These names can subsequently be used as queries for a text-based catalogue search returning only those records relating explicitly to the specific geographical area of interest.

528 Lancaster, L. R. and D. Bodenhamer (2002) 'The Electronic Cultural Atlas Initiative and the North American Religion Atlas,' in *Past Time, Past Place: GIS for History*, ed. Knowles. Redlands, CA, ESRI Press (pp. 163-178)
529 See http://ecai.org/imls2002/period.html for a report on progress in this work.
530 http://www.ecai.org/imls2002/

A number of prototypes have been built to test and demonstrate ECAI's systems. Map-based approaches involve the harvesting of information for subsequent geo-referencing, with latitudinal and longitudinal coordinates added to make place references explicit. The end product is a map-visualisation in two layers: one for place names (achieved using gazetteers) and one for geographical coordinates. These are overlaid to show the relationship and differences between geographical and geopolitical areas signified by dots. Clicking on a dot or place name calls up catalogue or bibliographical records pertaining to that area. Clicking on a city's dot or name retrieves its bibliographical records and reports which may be opened in full text, if required. These prototypes also incorporate adjustable timelines, allowing users the option of searching by time as well as by place, adding an extra dimension to the search and browsing capabilities.

The directors claim that linking online catalogues with online gazetteers could transform geographical searching. Search results could be visualised, and new kinds of queries supported with map displays.[531] Geographical and time information can potentially be considered a *lingua franca* transcending language differences and allowing searches to extend beyond traditional linguistic boundaries or limitations. The *ECAI digital atlas* is a global collection of hundreds of networked digital humanities projects linked by the clearinghouse and visualised through a GIS viewer. In addition to the creation and streamlining of humanities and social science content, the integration of GIS technology with the power of data visualisation and the convenience of shared, distributed content is innovative and welcome.

Results have been encouraging. In its first seven years, ECAI has secured the participation and informal affiliation of more than three hundred projects comprising several hundred scholars worldwide and representing a broad range of disciplines. In common with many other initiatives, the *TimeMap* software is in the process of being transferred from the exclusive property of a single institution, the University of Sydney, to an Open Source license, improving accessibility and opening up the initiative still further to the scholarly community.

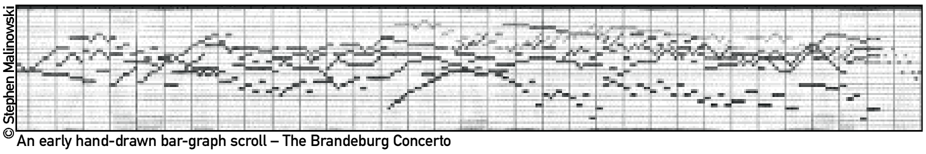
The Music Animation Machine[532]

The Music Animation Machine (MAM) was born of frustration with difficulties encountered by inexperienced musicians trying to follow the separate instrumental parts of a musical piece simultaneously while trying to develop a cohesive sense of it in its entirety. The project aims to develop visualisations of music that make obvious to non-musicians those aspects of musical structure that are understood by composers and theoreticians.

While its development spans many years from the 1970s to the present day, the project is small scale with most of the work done by solo developer Stephen Malinowski on a hobby basis. In Malinowski's own words, the idea for the Music Animation Machine "started with a hallucination… the flag of an eighth note extending like a ballet dancer's arm; pairs of notes moving in parallel thirds and sixths like pairs of dancers stepping hand-in-hand."

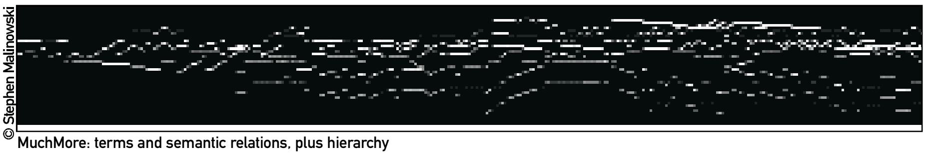
531 Buckland and Lancaster (2004) 'Combining Place, Time, and Topic: The Electronic Cultural Atlas Initiative'

532 This case study is based on an email interview with Stephen Malinowski, creator of the **Music Animation Machine**. The interview took place during August 2004.
http://www.well.com/user/smalin/mam.html; http://www.musanim.com/



© Stephen Malinowski

An early hand-drawn bar-graph scroll – The Brandeburg Concerto



© Stephen Malinowski

MuchMore: terms and semantic relations, plus hierarchy

After viewing condensed scores, Malinowski developed a paper bar graph scroll, with the durations of notes indicated by the length of the bars and individual instrument parts given in different colours. In 1981, he began work on an animated version. The first digital incarnation of the Music Animation Machine was implemented on an **Atari 800**. According to Malinowski, "[t]he animation was jerky and it sounded like a 1980s video game, but it worked!" The musical data were tedious to convert, with a two-minute piece taking around a week to input. The development of MIDI as the standard for the exchange of music data allowed the next version of the software to receive its input directly from a MIDI keyboard. In 1986, the software was redeveloped for the **IBM** PC.

Malinowski was encouraged by visualisation expert Edward Tufte to produce videotapes as learning and demonstrations tools.[533] The project continued to develop throughout the 1990s with additional functionality such as visualisation of tonality, harmonics, intervals, timbre and the interaction between different instruments.[534] Several questions were considered: what was the developer interested in at the time? Would this approach be effective? What was it feasible to implement, given limited time, financial resources and skills?

After various improvements, the decision was made to demonstrate the MAM by recording animations onto commercial videotapes. Yearly sales peaked in the mid-90s at around $11,000 (€8,980). The examples on the *First Demonstration Reel* (1990) covered a wide selection of musical styles and were intended to demonstrate the range of musical features the MAM was capable of showing. It is available free to qualified education institutions and libraries. Details for acquiring the tapes are available on the project Web site.[535] In terms of the visualisation, Malinowski says:

> Once the Music Animation Machine was operational, it was obvious how much was missing from it: you couldn't tell anything about timbre, very little about harmony, not much about rhythm... So I started trying to figure out how to enhance the display. The first thing I experimented with was tonality, as based on the "perfect fifth." The idea was that the colors in the artist's "color wheel" could be applied to notes in a way that showed what was going on in the harmony.

533 Malinowki: "Tufte contacted me in the winter of 1989 and encouraged me to release samples commercially; the first of these (First Demonstration Reel) was sold in the Spring of 1990. The development of alternative forms of visualization ran in parallel with this (and continues to the present). One of the alternative techniques (the use of color to show harmony) made it onto the 1996 Second Demonstration Reel; several others are on the History video (which, however, is not available commercially)." See also http://www.edwardtufte.com/tufte/

534 These experiments are described in more detail on the History of the Music Animation Machine Web site at http://www.well.com/user/smalin/mamhist.htm

535 http://www.well.com/user/smalin/video.html

In order to help users distinguish between instruments, Malinowski used different shapes to represent different parts, e.g. the flute part is an ellipse, the clarinet a rhombus, and the bassoon a star-shape. Further experimentation with shape included presenting currently sounding notes as solid, vivid rhombi in the centre of the display and recently heard notes as hollow shapes that gradually fell and faded away. Further experiments with visualisation of tonality and harmony yielded mixed results. Other experiments in the potential for stimulating deaf infants and encouraging their speech via visual stimuli have been carried out in conjunction with Willis Pitkin of **Utah State University**.[536]

While there has been no formal evaluation of the Music Animation Machine, the project has enjoyed success in different ways. The original scrolling bar-graph score has been used successfully in educational contexts. The demonstration videotapes have been used in music history, theory and appreciation classes from elementary school to college levels, and have been found to be an effective tool in teaching about musical structure. It is hoped that music teaching tools such as the MAM that make musical structure (usually understood only intuitively by most people) more obvious will have an important impact on music education in the future. In 2000, the MAM began to be broadcast on cable television channel **Classic Arts Showcase**, which has resulted in it being seen on television by millions of viewers each year.[537]

Scenarios

GPS, Visualisation, Visitor Studies – Part 2

In the last scenario of the Location-Based Systems section (above), the manager of a built heritage centre is concerned with the erosion and damage caused by increasing numbers of visitors. Each visitor is supplied with a GPS receiver which monitors and stores the position of each user at regular intervals. Data from the receivers are fed into a database when the GPS receivers are returned to the desk at the end of each visit.

Once an appropriate amount of information has been gathered, the positioning data are fed into a visualisation algorithm which dynamically maps the movement of visitors around the site. Visitor flows are depicted in different colours according to the number of visitors onsite at a given time, the climate conditions and time of year (which may affect erosion levels), and the length of time elapsed since the pathways were last changed. The system also flags up potential overcrowding danger spots where the management may wish to erect signs or protective fences.

This new project leads to the collection of a very large amount of positioning data which necessitates a robust data management strategy for the IT team. Backup is performed routinely and the database tables are mirrored on another computer, a fallback plan should anything untoward happen to the live tables. While the backroom staff is working out how to cope with the huge amount of data, individuals begin discussing other potential uses for the data. One bright spark suggests an interactive visualisation for visitors' use and the team sets to work designing such a system. The system allows visitors to track their own movements around the site from the comfort of a post-visit sofa in

536 http://www.well.com/user/smalin/hist29.html
537 http://classicartsshowcase.org/. Articles and reviews are available at http://www.well.com/user/smalin/reviews.htm

the visitor centre. The paths traced by the visitors can then be linked to images of exhibits and positions of other visitors, enabling them to see how their paths diverged and re-converged over the course of the day and how long they spent at each exhibit. The data collected can be reused (and re-visualised) for purposes including marketing and exhibition planning, publicity materials and sponsorship/funding applications.

Dynamic video objects in a sports museum

The curator of a sports museum is looking for ways to provide visitors with a greater sense of involvement with the exhibits. Visitor figures are fairly steady but the curator feels that greater connections could be made in the museum through the participatory nature of sport and learning about historical sporting figures and events.

The approach the museum has traditionally followed presents artefacts such as jerseys, match balls and souvenir programmes in a straightforward, no-frills manner with video footage of great sporting moments. Interactive programmes have recently been introduced which allow visitors to explore multimedia presentations of famous events. While these have proven initially popular, informal observation and evaluation show that they foster a more solitary visit experience and do not encourage discussion and interaction *between* visitors. However, visitor interaction has blossomed unexpectedly around the video displays where groups gather to discuss and debate their favourite tactics and plays.

The curator begins looking for a way to merge the discursive nature of the video displays with the engaging nature of the standalone interactive cabinets. Returning from a conference, a colleague mentions a project presentation she saw there which used dynamic on-screen video objects which followed a selected figure through subsequent frames of the film.[538] The curator sees an opportunity here and immediately gets in contact with the academic team responsible, enquiring about the availability of the software they used and whether it might be modified for a sports environment. To the curator's delight, the academics reveal that the project is Open Source, meaning the code can therefore be downloaded, modified and redistributed freely.

After downloading and studying the source code, the museum's IT department alters it to suit the museum's needs and applies a new interface simple enough for inexperienced museum visitors to use. After adding extra functionality, including adding external links to existing materials, the developers embed the updated code into the existing interactive system and text it with an invited audience of frequent visitors.

With the new system, visitors are able to stand at linked terminals and discuss video footage of great tactics/plays in real time. The operators have greater control over the video playback mode, the ability to slow down, pause and rewind the action, and to select key players to watch over successive scenes. The archive footage can also be sped up using an intuitive control wheel in order to demonstrate patterns (such as racing lines in cycling and motor sports) more clearly, with the dynamic markers leaving persistent traces behind them like trails of car headlights in a long-exposure photograph.

The system undergoes further development by another museum. More layers can overlap and the dynamic markers themselves are made more attractive and involving.

A breakthrough development comes from the sport of ice hockey where the league

538 See for example Toklu, Fischer and Liou (1999) 'Dynamic marke rs for collaborative discussion on video content,' Siemens Corporate Research Inc. Available online at http://www.spie.org/scripts/abstract.pl?bibcode=1999SPIE.3972..369T

managers, in conjunction with a major television network, agree to mark helmets and pucks with reflective material thus allowing player positions to be ingested directly into a visualisation program for commentary purposes. The system can also be used as a more accurate judge of whether or not the puck crossed in a close line call, allowing more precision than the traditional video footage.

Documentation of actor performances in a play

An academic is interested in exploring the differences in dramatic performances that may be forced upon touring productions by theatrical venues. His theory is that the physical features of a theatre have a greater effect on the success of performances than most scholars suspect. Ideally what the academic wants is a system which allows direct comparison of performances in a visual fashion with tools to match the movements of actors from scene to scene and marked-up scripts and performance notes available during the computer-assisted study of contrasting shows.

Employing a young tech-savvy graduate on a fixed-term basis and bringing two postgraduate theatre studies students on board as part of their ongoing assessment, the scholar films every performance of a touring company's latest play using three cameras in fixed positions. After the tour, he uses film analysis techniques on the digital videos to store the movements of actors onstage and is able to overlay and manipulate stills from two or more performances in order to compare their differences.

Having compared the results for a dozen performances/theatres, our academic's findings back up his initial ideas regarding the effects that different stages may have on a performance and also, in particular, the dramatic dynamic between the players. Although there are many other factors that will influence the effectiveness of a performance (such as audience size, familiarity with the script, actor confidence, and so on), he finds that a small stage may lead to a more intimate and powerful show while a large one may lead to bombast and a certain loss of subtlety.

Crucially, the software is designed to facilitate the simple and user-friendly repurposing of mark-up for disciplines other than dramatic acting such as television broadcasts, choreography and sporting events. The mark-ups produced can be cross-referenced with external resources, including stage directions and theatre dimensions, maps and texts, thus providing visual depictions of a variety of performance environments across a great range of purposes.

At the project's end, the postgraduate students continue refining the techniques they have developed and, with help from a forward-looking funding agency, they each begin exciting doctoral research into the uses of new technology for the computer-assisted analysis of theatrical and other performances. The system can also be used to help actors and directors prepare for forthcoming tours where the characteristics and effects of the different stages are already known.

A world-map of cultural institutions

A researcher in a European cultural heritage project is preparing to attend a symposium in Madrid which will involve his first visit to the Spanish capital. The researcher has a few spare hours before his return flight and he is delighted to learn by chance that the famous Prado museum is home to Diego Velázquez's *Las Meninas*, a painting of which he is more than fond.

On the flight home, it strikes our researcher that there is no single resource on the

Internet where the user can key in the name of an artwork and be told a definitive location. Spotting a gap in the market, he gets to work consulting colleagues on the logistics of putting together such a resource. After setting up a discursive, interactive *Wiki* Web site, interest in the project grows with support pledged from many corners of the heritage world. In the interests of fostering greater awareness of collections and initiatives, an official consortium is put together with the aim of producing, in the first instance, an interactive visual map of cultural and scientific heritage institutions across Europe and eventually expanding it to cover the world.

From suggestions filed to the Wiki, the visualisation team is familiar with interfaces such as **GNOD** and **Music Plasma**, both of which represent innovative relationships between musicians and genres. Taking a lead from these unique visual interfaces, the team creates a relational database of cultural institutions and collections which can be represented interactively and dynamically on the Web. The system represents organisations with icons, their sizes determined by factors such as annual budgets and visitor figures – both real and online. Larger institutions are represented by larger icons. Thematic links (shown as coloured bands of varying thickness) can be drawn between institutions according to carefully managed metadata. Using data collected from existing initiatives the team members begin to plot relationships between institutions on a country-by-country basis, focusing on attributes such as content types, special collections and mission statements.[539]

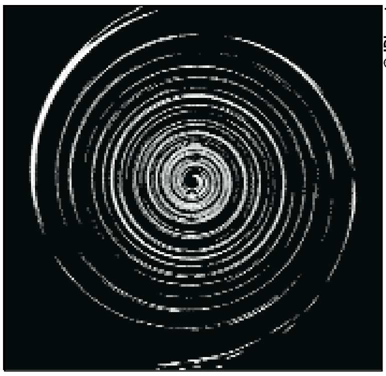
Problems crop up when it is pointed out that many artworks have both official and unofficial names: Velázquez's masterpiece, for example, was formally known as *The Family of Philip IV* in English, *La Familia de Felipe IV* in Spanish, and so on. This necessitates the integration of natural language tools to permit a certain degree of latitude in searching the resource and a robust cataloguing strategy.

The European pilot version is a hit with ordinary users and heritage professionals and funding is soon secured to expand the database beyond Europe and in more depth than just the most attractive and popular artworks. The project thus becomes a valuable worldwide resource, accessible by all via the Internet and customisable using skin technology to allow users to choose means of display most suited to their abilities, interests and tastes.

4. Advantages and Disadvantages

Introduction

In common with most types of software, visualisation tools have become increasingly sophisticated in recent years: it is now technically feasible to present information in richer and more complex graphical forms than ever before. Most desktop computers are sufficiently powerful to display impressive graphics and run all but the most complex software presenting information with clarity



© IDL.net

An IDL Galaxy map: Each pixel dot is a one-to-one map of an IP address of cyberspace, and colour coded according to domain type.

539 See for example those listed at http://icom.museum/mus_stats.html

and impact. Perhaps the main issue with visualisation technology is the question of complexity. Some information structures are simply too complex to be adequately represented using traditional means and require selective handling to present them in the best ways. One benefit of advanced data visualisation techniques over traditional approaches is the ability to 'drill down' into and manipulate the data while at the same time preserving the context of an entire domain. The lack of experienced technologists, combining technical and communication skills with common sense and a good eye, is another problem. Without these qualities it is difficult to envisage the creation of effective, accurate, efficient and aesthetic visualisations by and for the heritage community.

Advantages

'A good image is worth a thousand words' – This widely accepted idea is based on the fact that humans analyse visual information better than written text. One could add here that images may overcome language barriers, allowing the information to be understood faster.

Improved understanding of the general picture –Visualisation of data can present users with an easy means of quick contextualisation, highlighting general tendencies in a field where the number of objects in the collections (real or virtual) is often measured in thousands. Of course, the understanding of graphs *does* require a certain type of user literacy; inexperienced users are likely to understand simple graphs but, perhaps, not the more sophisticated types.

Improved possibilities for data analysis and study – Collection managers and curators can use data visualisation to analyse and study their collections and visitors. Comparison between collections and institutions becomes a possibility where multiple collections use similar data analysis methods and information and trends can conceivably be shared between linked organisations.

New points of view – Data visualisation methods can lead to new knowledge and new interpretations about information. Hidden or obscure patterns may emerge and new connections may be drawn from what was previously considered disparate data.[540]

Disadvantages

'A bad image takes a thousand words to explain' – Where a good image can save time and effort, a bad image can be confusing or misleading. For this reason, data visualisation methods must be considered very carefully with particular attention to the anticipated audience and the meaning the visualisation is intended to convey.

Risk of poor data quality – When the methods and/or data used are not of good quality, the results produced by visualisations may be misleading and may form false notions among users. The choice of appropriate methods and data analysis techniques requires not only training but also a great deal of common sense and experience.

Cost issues – The cost of visualisation scales from very low (inbuilt spreadsheet graph functions) to sophisticated dynamic packages incorporating database connectivity. In the case of GIS, the data collection process can be both time-consuming and difficult, requir-

540 For a practical application of this, see 'Scientists seek "map of science,"' BBC News, April 7th 2004 http://news.bbc.co.uk/2/hi/science/nature/3608385.stm

ing highly trained staff to ensure accurate measurements. The creation and maintenance of a visual GIS will be one of the more expensive software decisions management are likely to make.

Introducing the Technology

Fundamentals

The introduction of data visualisation methods requires substantial preliminary planning. There are several central issues that should be discussed. The first question will be to identify the needs that the visualisation is to address and to consider the potential advantages and risks. What is unique about the collection/data that makes visualisation preferable to textual description? Previous experience will be most useful here, and if none is available in-house it may be worth consulting other institutions or paid consultants.

The dataset itself is of primary importance. If data are already available within (or accessible by) the organisation, they must be demonstrably 'clean' and complete. If new data are being collected the methods must be sound and reliable. It may be possible to purchase, borrow or rent data from external sources. This may be the best option if the organisation lacks the sufficient expertise or resources to carry out the collection process internally. If the dataset is dynamic, tracking and updating will take time, effort and resources.

It will be worth seeking other organisations already using similar data visualisation methods. What are the differences between the proposed system and the one already in place? Might a comparative analysis of data from a number of organisations be of interest?

Data visualisation may act as a useful tool for attracting visitors to an institution or in guiding them to exhibits or parts of a collection. Visualisations can be integrated into an institutional Web site and a well thought-out, interactive deployment may be very popular with real-life and remote visitors alike.

Selecting a Specification and Development Environment

Depending on the data visualisation needs, organisations should consider a number of technological solutions. For reference, Dr Barry Wilkins of the **University of Birmingham** gives an excellent list of potential visualisation solutions together with the data types and set sizes which make each appropriate.[541]

For simple and effective visualisations, the graph and chart functions of most spreadsheets will suffice. Some spreadsheets also have inbuilt data analysis functionality. Most computer users will have encountered a spreadsheet at one point or another and the creation of such straightforward visualisations will not necessitate much staff training. For more complex data manipulation, specialised statistical software can be used. Accordingly,

541 http://www.cs.bham.ac.uk/~bxw/vispatts/ A number of other techniques are outlined and demonstrated by Eoin Brazil of the **University of Limerick** in his presentation 'Information Visualisation in Information Retrieval,' available online at http://richie.idc.ul.ie/eoin/presentations/Information%20Visualisation%20in%20Information%20Retreival.ppt

this requires more knowledge than the first option but leads to more sophisticated results and more powerful functionality.

For geographical and spatial data, a GIS is a purpose-built solution but will require specialist expertise to deploy and maintain.[542] Different data types may have their own specialised tools, e.g. the collection of 400,000 maps and 4,000 atlases at **Penn State University Libraries** used to provide GIS assistance for customer projects,[543] or the layered digital atlas with GIS functionality for archaeological excavations and research into the city's urban development at the **Roman-Germanic Museum** in Köln, Germany. [544] Again, the use of such tools requires specialised training.

In order to make the right choice, the institution's decision-makers must have a clear idea about the different stages of the visualisation process, knowledge of the data types involved and an understanding of the visualisation techniques to be applied. Smaller organisations may require the services of a private consultant.

Technological Infrastructure Issues

Data visualisation techniques seldom require expensive additional hardware and software. In fact, many software tools used for visualisation, such as spreadsheets and presentation software, are basic and widely known by many computer users. Statistical software tends to be more complex and will require specialist training. One potential difficulty is that inappropriate visualisations may lead to a misunderstanding of the information and it is fair to say that what is essential in the visualisation process is not the technology, *per se*, but a proper understanding of the data, methods and visualisation techniques.

Thinkmap, for example, is a software product that can be used for various visualisation tasks.[545] Its architecture includes a core which enables the dynamic and asynchronous flow of data, while plug-ins, listeners, filters, and maps offer additional functionalities. The user interface is separated from the back-end, and the user cannot see the complexity of the core data presentation.

An interesting application of the software was deployed for a presentation by the **Motorola Museum and Archives**. The institution's aim was to develop an "online, self-guided learning center by which Motorola employees across the globe could explore the company's rich history through a digitised archive of textual, visual, and audio artifacts."[546] *Thinkmap* was used to immerse the user in the company's historical and technological perspectives.

Staff and Policy Issues

Four groups of staff members will play key roles in the application of data visualisation technology: (i) data analysts; (ii) researchers/customer-facing staff; (iii) managers; and (iv) Web designers.

542 The introduction of GIS systems is covered in much greater detail in the section on Location-Based Systems, above.

543 http://www.libraries.psu.edu/maps/

544 http://www.museenkoeln.de/roemisch-germanisches-museum/ For many more please see Appendix: Products and Vendors.

545 http://www.thinkmap.com/

546 http://www.thinkmap.com/casestudies_motorola_history.jsp

Data analysts should advise on the methods and techniques to be applied in the data visualisation process. Their role will also involve ensuring the data are clean and complete. From their knowledge of other institutions and patrons, research and customer-facing staff can provide invaluable information about the needs that should be satisfied. Depending on experience, researchers might also have ideas about data analysis and visualisation methods and tools. Management's role is to coordinate the effort and find the best match between operational needs and the resources available. Depending on the formulated organisational and user needs, management may decide to use external advice or work on issues related to data visualisation within the organisation.

Given their experience with visual presentations, Web designers and coders will be useful not only for incorporating data visualisations on the Web site but also for providing general advice and guidance whether the visualisation is intended for the Web or not. Visual thinking is a gift and, as such, gifted staff should be involved as much as possible.

Telepresence, Haptics, Robotics

Executive Summary

Covering a huge spectrum of uses from Open Source instant messaging to underwater archaeology, telepresence, haptics and robotic technologies hold a wide range of potential applications for the cultural and scientific heritage sectors. Their scale of deployment costs can range from a few Euro to several hundred thousand but it is difficult to imagine a setting in which one or more of these technologies would not be beneficial. As costs fall and the concepts become more familiar, we can expect to see a rise in the deployments of these technologies throughout the sector both in-house and online.

Telepresence is defined as "a sense of presence in a mediated environment, wherein the user experiences the computer-mediated environment as less mediated than it actually is."[547] A telepresence system will consist of three sub-systems: the interface between the user and the communications link, the communications link itself (which is generally a telephone line) and the remote site which interfaces with the communication link and possibly another remote user. Small cameras, microphones and speakers are usually used to provide feedback and head mounted displays may be used if an enhanced sense of immersion in the system is desirable.

Haptic technologies involve the sense of touch in computing. They are sometimes known as 'force-feedback' technologies due to the forces exerted on the user by the device's motors. Haptics is very much a device-driven technology with input/output peripherals ranging in price from around €30, for a **Sony** *DualShock2* controller with vibration function, to around €50,000 for a top-of-the-range **SensAble** *PHANToM* haptic interface with six degrees of freedom. *Cutaneous* (tactile) devices are often included under this banner although they differ in approach with a focus on sensation rather than movement.

Haptic devices come in many forms including pens, gloves, joysticks/joypads and force-feedback mice. Normally used in conjunction with a visual display, haptic devices enable users to manipulate virtual representations of objects and artefacts from remote workstations. Web-delivered haptic exploration is beginning to mature and collaborative haptic sessions which take network delays (or 'latency') into account are now emerging.

Robotics is that branch of engineering which involves the conception, design, manufacture and operation of robots, i.e. machines that are specially designed to perform a particular task (or range of tasks). Robots can be

547 Steuer, J (1992) 'Defining Virtual Reality: Dimensions Determining Telepresence,' in *Journal of Communication*, 42(4), pp 73-93.

controlled directly by a human operator or can work independently, controlled by computer. It has been said that there are as many types of robots as there are tasks for them to perform but lower-price, general-purpose robots are available which can be deployed in a variety of roles.

Each of these three technologies has been developed over a number of years, and will be familiar to just about everyone who has ever watched a science fiction movie. Haptics is commonly used in training and hazardous situations, where the potential cost of error (to health, wallet or both) is great. It is easy to see how this technology may translate to a cultural heritage setting: representations of priceless artefacts can be explored from a distance with the originals in no danger from clumsy handling. Unsophisticated haptic devices are also found in many homes in the form of games console controllers which vibrate at key points to involve the player in a more physical way. Telepresence is often used in surveillance and in conjunction with haptics in dangerous situations such as nuclear work, space/subsea exploration, remote surgery and entertainment. The conjunction of multiple human users in a telepresence environment without a noticeable shortfall in experiential quality has been termed *telereality*.[548]

For the heritage sector, haptics can be used to add an extra dimension to learning and exploration and to improve access to materials. Robotics and telepresence can be combined to provide virtual representations in distant museums/galleries to map uncharted terrain and compile data for virtual reality models. It is not difficult to imagine how telepresence, haptics and robotics could combine in the future to meet a huge number of human wants and needs. While the costs of advanced haptic devices remain prohibitive, it is expected that these will fall in time. Simple telepresence is less expensive (Instant Messaging is itself a form of telepresence) and entry-level robotics kits can be bought for less than €30.

Introduction to the technologies

Telepresence, haptics, and robotics technologies seems set to greatly improve the quality of experience of remote users of cultural heritage materials. They offer vastly better means of interacting with real and virtual artefacts, and a number of other benefits ranging from preservation to entertainment, from access to discovery. Of the three technologies, robotics will probably be the most familiar to the majority of readers although many will have experienced haptic technologies without necessarily being aware of them. While haptics and telepresence are still in their infancy, their development has been rapid and their potential is clear to see. Falling prices and continued advances in Web technology should bring them within the reach of all sizes of institutions.

The most important benefits these technologies will bring are likely to be found in their conjunction, but the three technologies covered here are sufficiently different to merit individual treatments in the first instance before discussion progresses to consider them in various combinations. This section is therefore split into three shorter sections, each devoted to a distinct technology.

548 See Hickey, S., T. Manninen and P. Pulli (2000) 'TeleReality – The next step for Telepresence'

Telepresence

Background

The word *telepresence* was coined by Marvin Minsky in 1980 but it has taken some time for the definition to settle.[549] William A.S. Buxton defines telepresence as "the use of technology to establish a sense of shared *presence* or shared *space* among separated members of a group", while communications researchers Lombard and Ditton take a wider view, defining telepresence as "a mediated experience that creates for the user a strong sense of presence and entails an illusion of non-mediation".[550]

Telepresence covers two main objectives: the abilities to *observe* and to *participate* in a remote setting. In essence, telepresence systems are a natural progression from video conferencing. Their importance lies in the fact that they enrich communication with non-verbal aspects such as gestures, eye contact and spatial perception while, at the same time, providing many of the administrative functions that users need such as communication logging and file transfer.

An early example of telepresence is the *Mercury* project carried out between 1994 and 1995 at the **University of Southern California** (USC) in Los Angeles. This project connected robotics and archaeology in an interactive art installation. Over a seven-month period, the project system allowed online users to observe and participate in a remote setting through a tele-robot agent. Users were asked to discover artefacts hidden in sand in a laboratory and to identify and discuss their findings. The project Web site received over 2.5 million hits during the experiment. A follow-up experiment was carried out at USC between 1996 and 1997: the *Telegarden* exhibit at the *Ars Electronica Center*.[551] This allowed Web visitors to view and interact through an industrial robot arm within a remote garden of real plants. Around 9000 Web visitors took part in the experiment, tending the garden from remote locations.

Where and how telepresence is currently used

The range of systems that can be considered as types of telepresence begets a wide spectrum of potential applications from simple desktop clients to multimillion Euro scientific explorations. Individual uses include:

- **Hazardous environments** – Tasks which have to be fulfilled under conditions where humans cannot survive (but which nonetheless require human intervention) can be performed by robots controlled via telepresence. Such environments include monitoring chemical experiments, military operations, rescuing earthquake victims and underwater and space exploration.
- **Telemedicine** – There is considerable research underway in this area. In conjunction with robotics and haptic technologies, telepresence systems offer the possibility

549 MINSKY, M. (1980, June) Telepresence. Omni, pp. 45-51.
550 BUXTON, W. (1992). Telepresence: integrating shared task and person spaces. Proceedings of Graphics Interface '92, 123-129. http://www.billbuxton.com/shared_space.html Lombard, M., Ditton, T. (1997) "At the Heart of It All: The Concept of Telepresence", in **Journal of Computer Mediated Communication**, 3, (2), S. 6-21.
551 http://www.aec.at/en/index.asp

of performing remote diagnostics and even remote surgery.[552]

- **Training and education** – Telepresence systems enable students to participate in the exploration of otherwise inaccessible locations such as undersea objects, ancient archaeological sites, monuments and museum exhibits.
- **Surveillance and security** – Autonomously-operating sensors can be used to monitor sensitive areas and sound alarms in the case of security breach.
- **Commerce** – In advertising and sales, telepresence is used to demonstrate objects on sale such as real estate and holiday packages. Recent research has shown that customers tend to react better to sales approaches via text messages than to unsolicited telephone calls.[553]
- **Entertainment and tourism** – Telepresence systems can be incorporated into exhibitions and leisure complexes allowing potential visitors to gain a sense of place prior to an actual visit or to study objects when a real-life visit would be impractical.

Haptics

Background

The word *haptics* refers to the science of applying the sense of touch in human-computer interaction. Haptics is often used as a catchall term to cover a variety of distinct sub-types, including *proprioceptive* (general sensory information about the body), *vestibular* (the perception of head motion), *kinaesthetic* (the feeling of motion in the body), *cutaneous* (sensory information from the skin) and *tactile* (the sense of pressure experienced through the skin).[554]

The roots of the haptic technology can be traced back to 1818, when Professor Ernst Weber started to explore the anatomy and physiology of human senses. Modern research really began in the early 1990s when Greg Burdea of **Rutgers University** introduced a portable force-feedback glove which provides the feeling of an applied force. The same decade saw the launch of the first commercial haptic devices, including **SensAble**'s *PHANToM* haptic arm, **Immersion Corporation**'s *Impulse Engine* (a simulation device for abdominal surgical procedures) and *CyberGrasp* glove, and **Logitech**'s *WingMan Force-Feedback Mouse*.[555]

With the growing popularity of the computer gaming industry in the mid 1990s, force-feedback joysticks and mice became increasingly familiar to a broad range of users. Since then research on haptics has continued with increasing intensity, with the aim of developing systems and devices that can reflect the details of the human sensory system in a much more realistic and instinctive fashion.

Principles of haptic technologies

Haptics is very much a device-driven technology and cannot be experienced without

552 See BBC News, August 20th 2004, 'Virtual veins give nurses a hand' for images and examples of haptic applications in telemedicine. http://news.bbc.co.uk/1/hi/technology/3576664.stm
553 http://www.instantservice.com/benefits
554 BREWSTER, S. 'The Impact of Haptic "Touching" Technologies on Cultural Applications', http://www.dcs.gla.ac.uk/~stephen/papers/EVA2001.pdf
555 http://www.logitech.com/index.cfm/about/pr/release/US/EN,contentid=1160,year=1999

specialised hardware. Haptic devices are mechanical interfaces that facilitate communication between a user and a computer. These devices allow users to touch and sense two- and three-dimensional objects in virtual environments and telepresence systems (see below). Haptic devices differ from standard peripherals such as mice and trackballs in that they are input-output devices, i.e. they register user manipulations as input while, at the same time, provide touch sensations or forces as output. Touch-enabled devices convey forces to the user's hand or fingers under the control of a computer. Special hardware components located inside the devices allow the transfer of tactile and motion data.

Types of haptic devices

There are two main types of haptic devices: ground-based and body-based. *Ground-based devices* include pointing devices, such as touch enabled computer mice and force-feedback game controllers. Examples of haptic mice include the **Logitech** *iFeel Mouse, iFeel MouseMan*, and *Wingman* series.[556] The best-known haptic device is **SensAble**'s *PHANToM*, a peripheral closely related to the mouse but which allows interaction with objects in a three-dimensional environment.[557] Similar functions are performed by **Force Dimension** products, including the *Omega* and *Delta* haptic devices.[558] Game controllers include joysticks, gamepads and steering wheels used in computer games. Active game controllers include **Microsoft**'s *Sidewinder* series, **Nintendo**'s *RumblePak* peripheral, and the **Sony** *DualShock2* controller.[559] It is worth noting that computer games are and seem likely to remain an important test bed for touch-enabled devices and user interfaces.

Body-based devices include gloves, suits and exoskeletal devices. Typical representatives of this category are **Immersion Corporation**'s range of glove products: the *CyberGlove*, which contains up to twenty-two sensors located over or near the joints of the hand and wrist, monitor the motions of the hand and fingers; the *CyberTouch*, with vibrotactile feedback on each finger and the palm of the glove; and the *CyberForce*, a hand and arm force-feedback device. [560] All **Immersion** haptic products are driven by the dedicated *Virtual Hand software* development kit (SDK).

Immersion also produces the *CyberGrasp*, an exoskeleton device which provides a resistive force-feedback to a user's fingers allowing manipulation of computer-generated 3D objects.[561] Other representatives of the exoskeleton haptic product group include the *Dextrous Hand* and *Dextrous Arm* designed and manufactured by **Sarcos Incorporated** in collaboration with the **University of Utah**'s *Center for Engineering Design and MIT's Artificial Intelligence Laboratory*.[562] The interface designed for the **Museum of Pure Form** is another example of an exoskeletal haptic arm.[563]

Touch enabled suits are not yet widely available and tend to be created for research purposes only. MIT's *Cutaneous Grooves* project produced a haptic suit lined with vibrating transducers that allow the wearer to experience a full-body, vibrotactile sensation coupled with accompanying music.[564] A commercial product, the *Aura Interactor* – a vest

556 http://www.logitech.com
557 http://www.sensable.com
558 http://www.forcedimension.com/products
559 http://www.microsoft.com/hardware/sidewinder
560 http://www.immersion.com/3d
561 http://www.immersion.com/3d/products/cyber_grasp.php
562 http://www.sarcos.com/telerobotics.html
563 http://www.pureform.org/technology2.htm See the case study on the Museum of Pure Form, below, for more detail.
564 http://ic.media.mit.edu/icSite/icprojects/CutaneousGrooves.html

with actuators triggered by audio outputs creating body-pulsing vibrations – is no longer on the market but second-hand devices can still be found.[565]

Where and how haptics is currently used

Haptic technology, while not yet fully mature, has already proved useful in a wide spectrum of applications where the sense of touch could bring additional information to the user. These include:

- Innovative interfaces, including desktop GUI augmentation;
- Interfaces for visually-impaired users, such as the delivery of Braille texts;
- Education, including simulators for digital training and practice in expensive or dangerous scenarios such as medicine or the military;
- Physical rehabilitation and physiotherapy;
- Telerobotics and virtual environments;
- Computer Aided Design (CAD) tools;
- Entertainment (virtual reality arcades, gaming systems).

It is now possible to transmit tactile sensations over the Internet allowing users to experience and enjoy the simulation of physical contact when interacting with three-dimensional art objects and digitised sculptures. The **University of Southern California** has developed a prototype system for heterogeneous haptic collaboration over the Internet.[566] This system is based on a distributed architecture and provides for multiple users equipped with different haptic devices (including the *PHANToM, CyberGrasp*, and *iFeel* mouse) to share a common sense of touch, allowing them to exercise forces over shared virtual objects, or each other, at the same time.

Haptic technologies and the partially-sighted

The development of the Internet has facilitated access to information that was previously denied to those with visual problems or impairments. Blind or partially-sighted computer users can use Text-To-Speech (TTS) engines and/or Braille displays to provide access to onscreen text and Hypertext links. Such solutions, however, do not provide access to graphical content which is often where a sizeable amount of a Web site's meaning is held. Visually impaired users may find haptic access more suitable than the standard graphical user interface (GUI) approach or audio-assisted browsing.[567] Haptic interfaces may be more intuitive to use and capable of imparting more information about real-world objects than a purely descriptive interface could ever manage. Another advantage of haptic interfaces over speech-based interfaces is that speech technologies tend to be language-dependent whereas tactile devices can be used by a variety of users in a single, non-linguistic environment. Tactile devices are faster than speech-enabled interfaces and may be more instinctive. The *iFeelPixel* application, which links images with audio and

565 See a product review at http://www.riva3d.com/aura.html
566 See Haptic Collaboration Over the Internet, http://imsc.usc.edu/research/project/haptics/index.html A white paper on this work is also available at http://imsc.usc.edu/haptics/mutualtouch.pdf
567 Audio-haptic browsing is also possible. See Patrick Roth *et al.* "Audio-Haptic Internet Browser and Associated Tools for Blind and Visually Impaired Computer Users," http://vision.unige.ch/publications/postscript/2000/RothPetrucciAssimacopoulosPun_cost2000.pdf

tactile sensations, is designed specifically for use by people with sight and hearing problems and the **Logitech** *Wingman Force-Feedback Wheel* is especially recommended for blind users.

A further means for improving access for blind and partially-sighted users are gesture recognition techniques. Simple gestures can have natural and instinctive meaning for the user and these can be used to trigger tasks such as grabbing a virtual object or initiating a series of actions (akin to a macro) thus providing a reliable and low-cost means of interfacing. Tactile gloves can be used as gesture input devices while software routines determine and display the meaning of the corresponding sign. In this way, visual-gestural languages (such as sign languages) can be mapped and translated to computer readable forms, enabling communication for deaf or blind users. For deaf-blind users, haptic technologies may be the only way for certain information to be conveyed.[568]

Robotics

Background

Many recent human inventions (such as flying machines, space vehicles, and submarines) were envisioned long before their eventual creation. Robotics is an example of a technology that appeared in the twentieth century but with conceptual roots extending much further back. The word *robot* was coined by the Czech writer Karel Capek in 1917, but the idea of robotics dates back to ancient Greece. According to historical sources, a mechanical bird put in motion by a steam jet was constructed by the philosopher and mathematician Archytas of Tarentum in the fourth century BC. George Devol and Joe Engelberger developed the first modern robots for industrial use in the late 1950s and early 1960s.

Principles of robotic technologies

The **Robotic Industries Association** defines the industrial robot as "a reprogrammable, multi-functional machine designed to manipulate material, parts, tools or specialised devices through variable programmed motions for the performance of a variety of tasks."[569] Robots have three fundamental characteristics: how they sense, how they 'think' and how they act. In addition, robots can be classified according to their area of application and their appearance.

Where and how robotics are currently used

In his fascinating article 'The Humanoid Race,' Robert Capps outlines the recent progress made in robotic developments, with functions ranging from lifelike muscles, skin, and facial expression to sensory emulation, limb motion and balance. Japanese neuroscientist Mitsuo Kawato has called on his country's government to create a prize fund of 50 billion Yen to encourage the development of a robot with all the attributes (physical, cognitive, and emotional) of a five year-old child.[570]

568 For more on the interfacing of haptics for the visually-impaired see Maura Sile O'Modhrain and Brent Gillespie, "The Moose: A Haptic User Interface for Blind Persons," http://ccrma.stanford.edu/~sile/papers/www6-paper.html

569 Definition from Robotics Online, sponsored by the Robotic Industries Association: http://www.roboticsonline.com/public/articles/index.cfm?cat=113

570 http://www.wired.com/wired/archive/12.07/race.html

There are three basic groups of robotic applications:

- **Industrial applications**. Robots are frequently deployed in assembly lines (e.g. in electronic and automotive production), welding (in the motor vehicle industry), and packaging. They may be of special value when used in dangerous environments or for difficult manufacturing tasks such as materials handling, welding and coating, electronics manufacturing and in programmable and flexible automation processes.
- **Hazardous situations**. Robots are used for fire fighting, search-and-rescue missions, in the military for mine handling, unmanned reconnaissance, hazardous waste handling and in mobile tactical warfare. Remote controlled robot cameras have been used successfully to map submarine trenches and shipwrecks.[571]
- **Service robots**. According to the definition of the **International Federation of Robotics**, a service robot "operates semi or fully autonomously to perform services useful to the well being of humans and equipment, excluding manufacturing operations."[572] This category covers robots for personal and private use such as domestic robots which perform tasks like lawn-mowing and vacuum cleaning. These use intelligent navigation technology to clean floor surfaces without human intervention and are equipped with safety features including switching off when picked up or stuck. Entertainment robots (and toys such as **Hasbro**'s *Furby*) are expected to have the largest market share over the next few years.[573]

Healthcare robots can be used for a variety of purposes: in therapy, rehabilitation, assisting people with disabilities, robotic surgery and the transportation of materials in hospitals.[574] In science, robots are used in biotechnology and nanotechnology, drug discovery and hazardous chemistry experimentation. Robots can also be found in areas such as search and rescue, aerial inspection, law enforcement and movie making. **NEC**'s *PaPeRo* claims to be the first robot equipped with speech-to-speech technology allowing it to translate between two languages and even use colloquialisms.[575] The technology has since been ported to PDAs and travellers arriving at Japan's Narita airport can now hire handheld translation assistants.[576]

In 2002, the most popular deployments of professional robots were underwater (20%), cleaning (18%), demolition (15%) and medicine (12%). It is projected that in the period 2003-2006 the number of service robots will grow by 30,000 with the biggest demand being for medical robots (6,000), surveillance robots (3,800) and underwater robots (3,000).[577] The **Japan Robot Association** forecasts that the market for service and personal robots will equal the size of the industrial robot market in 2005 and, by 2025, will be four times larger.[578]

571 See the MOSS project for a fine example of such work. http://www.mossproject.com/
572 http://www.ifr.org
573 http://www.furby.com
574 The *Tug* robot from **Aethon Inc.** uses navigation technology to move hospital supplies, freeing up hospital personnel to spend more time with patients. http://www.aethon.com
575 http://www.incx.nec.co.jp/robot/robotcenter_e.html
576 http://news.bbc.co.uk/1/hi/technology/3513623.stm
577 Data for year 2002, published in *World Robotics 2003 – Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment*, (United Nations Publications), ISBN 92-1-101059-4, Press release available at http://www.unece.org/press/pr2003/03stat_p01e.pdf
578 Summary Report on Technology Strategy for Creating a "Robot Society" in the 21st Century, May 2001, Japan Robot Association (pp. 13). http://www.jara.jp/en/06_topics/pdf/report0105.pdf

Geographical distribution of robots

Robots are currently most popular in Japan, the EU, and the USA. It is estimated that at least 233,000 industrial robots are used in the EU, 350,000 in Japan and 104,000 in North America.[579] The same study estimates that in 2002 the total number of industrial robots was between 770,000 and 1,050,000. These figures are based on the estimation of an average service life of between twelve and fifteen years. Forecasts for the worldwide industrial robot market estimate an additional 91,000 units being shipped in 2006 with an average yearly increase of 7.4%. The EU market is estimated to reach 32,000 robots in 2006, an increase of around 6,000 on the figures for 2002.[580]

How the technologies work

Telepresence

A telepresence system is something like a cross between virtual reality and videoconferencing, with the attendant advantages of both. The primary difference between telepresence and VR is that users are not immersed in a virtual world but participate in another part of the real world.

Telepresence systems consist of a home location, a remote location and a communications link between them. The user location must be equipped with suitable hardware devices which provide the user with information about the remote location and allows it to act as necessary. Audio devices (stereo headphones), video devices (monitors, display screens, head mounted displays) and haptic systems (gloves providing touch sensing) can be used to provide feedback and joysticks, position tracking controllers and haptic devices can be used to perform remote tasks.

Telepresence systems can use different communication links between both locations (dedicated telephone lines, the Internet, mobile phones). The type of communication is selected depending on the technical parameters of the link such as the physical distance between home and remote locations, bandwidth requirements, transmission delay times, and cost considerations. The remote location must also be equipped with suitable hardware devices. Many of these will be similar to the equipment used in remotely controlled robotic systems taking into account the fact that telepresence systems always include a human controlled operating mode. Typical equipment at the remote location will include zoom and tilt cameras, sensors (microphones and touch sensors), robotic vehicles (wheeled or tracked), special robotic manipulators and end effectors. Remote locations are also typically equipped with a microprocessor-based system capable of control and signal processing including video signal grabbing and video stream compression.

579 **World Robotics 2003** – *Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment,* (United Nations Publications), ISBN 92-1-101059-4. Press release on http://www.unece.org/press/pr2003/03stat_p01e.pdf
580 Ibid.

Interactive telepresence

Telepresence systems can be divided into two categories, each with its own advantages and disadvantages: *interactive* telepresence systems with advanced videoconferencing features and *immersive* telepresence systems where users, represented as avatars, communicate and collaborate in virtual 3D worlds.

Interactive systems provide the capacity for sharing audio and video data with a distant site or collection of sites thus offering users a more 'realistic' experience. Since **Microsoft** and **Apple** began incorporating audio and video support in their popular free programs *MSN Messenger* and *iChat AV*, online chat systems now provide the simplest example of interactive telepresence.[581] In each system, the audio and video signals are generated by Webcams and simple desk- or headset-mounted microphones. The quality and realism will be dependent on the user's connection speed and bandwidth: a Webcam conversation held over a high-speed LAN will be much more involving than one delivered by dial-up connection between different continents. If smooth communication is a key goal, broadband is a must. Telepresence applications may offer the facility to place telephone calls via Voice over Internet Protocol (VoIP) technology.[582] One disadvantage of this is that unlike textual conversation transcripts, audio and video communication histories cannot be logged automatically, making record keeping difficult.

Traditional videoconferencing systems have a number of limitations, notably the lack of a facility for the exchange of documents and the lack of realistic face-to-face communication. Web conferencing systems are a further development in the ongoing effort to speed up decision-making and cooperative work. Some of the basic suppliers of Web based videoconferencing services are listed in the Appendix, below.[583] Interactive telepresence systems are designed to overcome the limitations of both video- and Web conferencing using Internet technology to provide a more realistic sense of involvement. System parameters such as audio quality, video quality, latency time, and document sharing all contribute to this. Some of the main players in the Interactive telepresence market and their products are listed in tabular form in the Appendix, below.

Immersive telepresence

Immersive telepresence systems are based on advanced 3D video technology, allowing users to meet and collaborate in a networked virtual environment. Participants can freely navigate and see themselves and others from arbitrary viewing points. Use of 3D avatars provides new options for interaction and collaboration. The user can interact with the environment, his or her own avatar and those of other remote 'visitors'. From a technical point of view, immersive telepresence systems are based on 3D video as an interaction medium with the user's own appearance scanned continuously and transmitted as a 3D image to a remote location. Here it is re-rendered into the virtual space and can be experienced by others thereby allowing users to share the same virtual space and to perform common tasks.

581 http://messenger.msn.com; http://www.apple.com/ichat
582 Voice over Internet Protocol
583 A more comprehensive list of Web conferencing software can be found on http://www.thinkofit.com/webconf/

Telepresence has been a key component in a number of recent research projects. The *Virtue* project began in 2000 aiming to create immersive telepresence in videoconferencing systems, i.e. a meeting space where the real and virtual worlds are mixed.[584] Participants at different locations are given the impression that they are sitting next to each other and are able to work co-operatively. **Hewlett Packard**'s *BiReality* project is subtitled "Mutually-immersive Mobile Telepresence" in order to provide an attractive and economically advantageous alternative to physical travel.[585] The system includes bi-directional video and audio communication hardware located on a mobile platform together with a limited haptic feedback. The *DHX* (Digital Ecological and Artistic Heritage Exchange) project began in 2002 and aims "to establish a networked virtual reality infrastructure and content development environment for museums and cyber theatres for mutual exchange of digital cultural and natural heritage".[586] Through the use of high-speed, transcontinental networks, the project envisions a shared, globalised and fully immersive experience for the sharing and exploring of cultural heritage content, experiences and performances.

Haptics

Introduction

There are two fundamental types of output used by standard haptic devices: *tactile feedback* and *force-feedback*. Tactile feedback refers to sensations detected by human skin such as surface textures, vibrations and heat. This kind of feedback can be applied in order to register contact with an object in a virtual environment. Force-feedback involves the use of motors and robotic manipulators to interact with human muscles thus providing the sensation of an applied force.

Haptic devices are complex hardware units that generate data when their effectors are manipulated by users and which then transmit these data to an interface controller. The information is further processed in order to define the exact position of the end effector. The co-ordinates of that position are then transferred to the computer which calculates whether a reaction force is required or not and sends the appropriate feedback data to the haptic device. Actuators (usually electrical motors) apply these forces to the user thus generating the required sensations. For example, actuators within the force-feedback joystick can apply forces to simulate the feel of encountering an obstacle or dragging a heavy object uphill.

The tactile characteristics of human sensors require higher operating frequencies than those used to refresh computer graphics. This difference in bandwidth necessitates the inclusion of dedicated controllers in haptic devices. Due to the computational complexity of the tasks to be performed, the devices are usually provided with their own processors, allowing the computer to dedicate its full processing power to the applications.

584 http://www.virtue.eu.com
585 http://www.hpl.hp.com/research/mmsl/projects/etravel.html
586 http://www.eurasian-dhx.org/

Programming and development of touch-enabled applications.

Touch-enabled applications are usually developed using dedicated software development kits (SDKs) which include algorithms and classes for driving haptic devices. Vendors of these SDKs include *GHOST, VirtualHand* and *e-Touch*. VirtualHand is a general framework for adding hand-enabled simulations or integrating hand-interaction into existing applications.[587] The SDK is based on three main components: a device manager which acts as a driver system for *CyberGlove, CyberTouch, CyberGrasp, CyberForce* and some third-party devices; a device configuration utility which is an interface for calibrating and configuring haptic devices; and the Virtual Hand Toolkit which is a *C++* development library offering support for collision detection, hand interaction management and force-feedback.

GHOST (the General Haptic Open Software Toolkit) is a multiplatform *C++* SDK featuring libraries of objects and effects which allow developers to integrate haptic sensations in various applications including engineering, education, telerobotics, military training, medical training, rehabilitation, physical therapy, entertainment or assistance of disabled people.[588] *e-Touch* fulfils the same functions as VirtualHand and GHOST and supports devices such as **SensAble**'s *PHANToM* and **Force Dimension**'s *DELTA* series.[589]

Applications for audio-, video- or button-generated force-feedback

Haptic feedback can also be generated from more familiar sources such as the Web. *iFeelPixel* is an application that provides audio-tactile sensations based on images.[590] As the user's cursor moves around the screen, computer-generated images will be represented by a combination of audio-tactile sensations via an Immersion *TouchSense* haptic device and a PC sound card. Thus, the software allows users to experience screen-bound images using haptic and auditory feedback. **Immersion**'s *TouchWare* gaming technology uses sound data to create sensations for force-feedback gaming devices, such as joysticks, wheels or mice.[591] *TouchWare* also allows force-feedback sensations to be associated with button presses from game controllers, bringing haptic technologies into home entertainment systems such as **Sony**'s immensely popular *PlayStation 2* gaming platform.

A note on PC graphics cards

Interactive haptic simulation and real-time 3D rendering require the use of high performance PCs incorporating powerful graphics cards which incorporate their own processors. Advances in desktop graphics are also a factor in the rapid development of cheap and readily available telepresence systems. In order to meet the demands of current applications, video cards have evolved considerably in the last decade. Where once these were simple devices for processing data and sending them to the monitor, modern cards can manipulate millions of polygons in a 3D scene in order to render realistic, immersive and interactive worlds.

587 http://www.immersion.com/3d/products/virtualhand_sdk.php
588 http://www.sensable.com/products/phantom_ghost/ghost.asp
589 http://www.etouch3d.org
590 http://www.ifeelpixel.com
591 http://www.immersion.com

A table detailing the specifications of some popular graphics cards can be found in the Appendix, below.

Robotics

Fundamental components

A basic robotic system will usually include the following components:

- **Body**: The design of a robot's body will depend on its purpose and tasks. Robots may resemble humans or may take the shape of a robotic arm, a moving platform, a pet toy or anything else depending on the requirements of the device.
- **Actuators**: These are hardware devices that control the movement of robot's parts. They can be electric motors or solenoids (driven by electric power), hydraulic systems (driven by liquids under pressure) or pneumatic systems (driven by pressurised air). Scientists at the **University of California in Los Angeles** (UCLA) recently announced that for the first time a *microrobot* was put in motion by the pulsing of a heart muscle. The '*musclebot*', as it is called, is expected to be applied in such diverse fields as medicine and spacecraft maintenance.[592]
- **Power supply**: Depending on the actuator type, robots may have to be supplied with compressed gas, compressed oil or electrical power.
- **Control unit**: This is used to control the whole system, and may include artificial intelligence if this is necessary. Computers are generally used to control robots due to their multi-functionality and flexibility. As a result, most robots can be reprogrammed and redeployed.
- **Sensory systems**: These provide robots with environment information and allow their interacting with the surrounding world. Such systems include infrared or ultrasound sensors to determine distances, charged-couple display (CCD) cameras with image-recognition software, sound sensors (usually microphones) with speech recognition software, and olfactory sensors for environments where smell is a factor.
- **End effectors and special manipulators**: Robotic arms may be fitted with different end effectors and/or special manipulators depending on the particular application. Typical industrial end effectors include clamps, grippers, blowtorches, drills, spray painters, tool changers, rotary joints and orbital sanders.

It is worth noting the obvious analogy between robotic components and the human body. Robotic sensors are equivalent to human senses, manipulators equate to hands or fingers, the power supply to the blood system and the control unit to the brain.

Types of robot

Depending on their structure and purpose, robots can be classified as fixed or mobile. Fixed robotic arms consist of separate elements interconnected by mechanical joints. These are usually used for manufacturing and production tasks and can be fitted with end effectors suitable to a particular application. Mobile robots are provided with a loco-

592 http://www.eurekalert.org/pub_releases/2004-02/ns-frm022504.php

motion system (wheels, tracks or legs) and most can be remotely controlled by radio, infrared signals or computer programs. *Autonomous* mobile robots can make decisions based on interaction with the surrounding world, *PC-Bots* can be considered as PC devices provided with robotic senses and capabilities, and *homemade* robots are designed and made by hobbyists using robot kits, computer parts and even parts of toys.

Robots can also be classified according to their generation. The first generation (of the 1970s) consisted of reprogrammable robots, most often robotic arms which execute repetitive movements. In the 1980s, second-generation robots added sensors for collecting data about the environment, and the third generation of the 1990s was the first to feature the use of artificial intelligence and autonomy. These factors are important in cases when it is too expensive to have a human operator or where it is impractical for a human to make decisions. An example of the latter scenario would be the use of robots in space when control signals from Earth would take too long to reach the robot.

Reliability issues

Robotic failure is defined as "any kind of problem which requires a human intervention."[593] Failures may be *uncritical*, when the operation of the robot does not stop, or *critical*, when the robot stops and requires attention from staff members. The *mean time between failures* (MTBF) is an important characteristic of robots used in public spaces such as museum exhibitions. For example, the study of sixty-four days' use of eleven *RoboX* tour guides at **Expo02** showed that for the 5,290 hours of operation when 283,000 visitors were guided by robots there were 2,097 failures most of which were critical (1,869).[594] This would mean that one visitor in 135 was witnessing a robot failure, assuming that the robot accompanies only one visitor per trip. If we suppose that an average of three visitors accompanied the robot, failures would have affected one visitor in 45. It is worth noting that MTBF values increased over time, meaning failures occurred less often. As an experimental deployment, typical errors were identified and overcome. This can be viewed as a form of testing.

Telepresence, haptics, robotics and the heritage sector

Introduction

Each of the three technologies featured in this section has uses for which it is uniquely suitable, and tasks that, without them, would be impractical if not impossible. The paragraphs below outline a few such situations. There then follow four case studies on real-life deployments of haptics, telepresence, and robotics. After the case studies we present fictional scenarios where these approaches could be put to good use in the near future.

593 TOMATIS N. et al., Design and System Integration for the Expo.02 Robot, In: Proceedings of the IEEE/RSJ IROS 2002 Workshop on Robots in Exhibitions, Lausanne, Switzerland, October 2002.

594 http://www.bluebotics.com

Telepresence for observing objects of art

The simplest use of telepresence in cultural and scientific heritage institutions is to allow the remote observation and discussion of objects. This usually involves Internet technology as a communication channel. In such cases, telepresence gives the sense of being in another place, for example through a Webcam which may be used to zoom the image or to study parts of special interest. Cameras can be fixed in a single position, providing only a minimal sense of involvement in the remote environment, or mobile, giving users much more control over their telepresence experience.

Telepresence used for real avatars in tour guides

Another interesting application of telepresence is the use of an avatar at the remote location to serve as an Internet user's virtual representative. The **Telebuddy** project (subtitled "Physical Telepresence for Visiting German Research Institutes in the Internet") uses a puppet to play the role of a physical avatar.[595] A human visitor carries the puppet during an actual visit to the exhibition and this broadcasts the visit to Internet users via a camera and a microphone.

In a more active setting, the avatar may be a robot which is controllable by the remote user via the Internet. In these cases the user can select where to go, what to see and how to see it. This was implemented in the **TOURBOT** project which combines robotics and telepresence for the remote visiting of museums.[596]

Tactile study of 3D models of works of art or museum exhibits

The use of haptic devices in the cultural heritage sector is most commonly connected with the presentation of objects. The possibility for the virtual study of artworks or artefacts based on highly realistic presentations of the materials is attractive and may in time become a staple part of museum Web sites. **The Museum of Pure Form** is a virtual gallery offering digitised sculptures from European and worldwide museums. Visitors can interact through touch and sight with three-dimensional representations of the sculptures.[597] A new term, *tangialities*, coined from 'tangible virtualities,' has been applied for virtual art exhibits made available for tactile study over the Web.[598]

A current fundamental concern which prevents the more widespread adoption of haptic technologies is that high-quality devices are expensive: haptic mice cost around €100 and the costs of specialised devices can reach tens of thousands of Euro.[599] The only way to overcome this at the moment is to install specialised devices in public places such as museums thus allowing large numbers of people to experience haptic representations.

595 HOFFMANN A., GOEBEL S. (2003) Designing Collaborative Group Experience for Museums with Telebuddy, Museums and the Web 2003, http://www.archimuse.com/mw2003/papers/hoffmann/hoffmann.html
See the case study, below, for more on Telebuddy.
596 http://www.ics.forth.gr/tourbot/
597 http://www.pureform.org For more on the Museum of Pure Form see the case study, below.
598 MILEKIC, S. (2002) Towards Tangible Virtualities: Tangialities, In: Museums and the Web 2002, http://www.archimuse.com/mw2002/papers/milekic/milekic.html
599 BREWSTER, S. The Impact of Haptic: "Touching" Technologies on Cultural Applications. Proceedings of the EVA 2001 conference. http://www.dcs.gla.ac.uk/~stephen/papers/EVA2001.pdf

Robots in automated library storage and retrieval systems

Automated Storage and Retrieval Systems (ASRS) in libraries are similar to industrial Automated Warehousing systems. A predecessor of ASRS called the *Randtriever* was installed at the library of the **Erasmus University**, Rotterdam in the 1960s. The principles of ASRS operation are quite simple. The objects (books, journals, videos, archival documents) are bar-coded or fixed with radio frequency identification (RFID) tags and placed in pallets or bins. These bins are located in an appropriate storage facility. (Unlike the traditional open shelves, here the space could be used up to the maximum height of the storage room.) When a book is requested (typically through the library catalogue or via the Internet), a robotic crane retrieves the bin holding the requested material and delivers it to the lending desk. The crane then returns the bin back to its place.

The issue has been raised as to whether it would be cheaper to digitise rarely used material rather than build sophisticated storage systems. Canada's **Irving K. Barber Learning Centre** estimated that digitisation of 1,444,250 volumes which will be stored in ASRS would cost $ 281,628,750, while ASRS equipment and construction would cost $ 7,685,700.[600] The retrieval time of materials is less than five minutes (and usually around 90 seconds) compared with twenty-four hours for materials stored outside the main library building. The ASRS at the **Oviatt Library** of **California State University** stores 950,000 less frequently used volumes (defined as books and periodicals not requested in the last three years).

According to Sarah Elizabeth Kirsch, an ASRS can store books in one twelfth of the space of open stack shelving and at a quarter of the cost.[601] It has also been claimed that books printed on acid paper stored in an ASRS will last forty years longer compared to storage on open shelves. This is due to the increased ability of storing materials in conditions suitable for preservation which is difficult in rooms with staff and visitors in constant motion.

A prototype free-moving robotic library assistant has recently been developed in Spain. It features cameras, sensors and grippers allowing it to locate and collect books. Professor Angel del Pobil of **University Jaume I** feels that libraries are a good place to introduce robots to public places, since "a library is a semi-structured environment".[602]

Robots as tour guides

The museum environment provides numerous challenges for robotics vendors. In the first instance, robots used in museums must be autonomous, robust and reliable. They also should be friendly and offer rich interaction including speech capabilities, 'facial' expression and a straightforward user interface.

Tour guiding is a challenging application of robots in the cultural and scientific heritage sector, especially in museums and exhibitions. Robots deployed in the cultural heritage sector form a small share in the service robot application area according to the

600 http://www.ikebarberlearningcentre.ubc.ca/ASRSfaq.pdf

601 KIRSCH S.E. (1999) Automated Storage and Retrieval Systems – The Next Generation: How Northridge's Success is Spurring a Revolution in Library Storage and Circulation. http://www.ala.org/ala/acrl/acrlevents/kirsch99.pdf

602 'Robots get bookish in libraries,' BBC News, 21st July 2004 http://news.bbc.co.uk/2/hi/technology/3897583.stm

World Robotics survey with only ten guide robots installed in museums up to the end of 2002 and twenty new installations expected by 2006.[603] The workshop *WS9 Robots in Exhibition*, part of **IROS 2002**, the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems in Lausanne, Switzerland, claims more cultural deployments of robots. In their introduction to the workshop, organisers Kai Oliver Arras and Wolfram Burgard wrote:

> The speakers of this workshop unite a seven-year operation experience with more than 90 robots that travelled several thousand kilometres in exhibitions and interacted with hundreds [of] thousands of people.[604]

Robots have been used in museum exhibitions to meet different organisational needs. In addition to the role of tour guides (which are an attracting factor for more museum visits), robots can be used for a number of other tasks such as welcoming visitors and providing initial information about the collection. They can also be focused on less popular exhibits by moving around and inviting visitors to accompany them to visit the hall. Robots can be used to automate the operation of video projectors or dioramas when needed thus avoiding unnecessary functioning when there are no visitors present.

In recent years, museums experimenting with robot tour guides have tried simultaneous deployment of multiple robots capable of communicating amongst themselves. This work is ongoing but the development of robot "communities" will be a step towards increased automation of cultural services.[605]

Robots at archaeological sites and underwater archaeology

In the previous examples, robotic systems act as labour-saving devices in activities which could be carried out by humans. They cut retrieval times in the case of the ASRS and entertain museum visitors in the case of museum tour guides. But robots truly come into their own in situations where human action may be dangerous or impossible.

Robots equipped with laser scanners and ground-penetrating radar have been used to assist in archaeological digs, helping archaeologists make decisions regarding which spots at an excavation are most promising.[606] They are also used to study inaccessible spaces of monuments such as the pyramids of Egypt. Among the earliest attempts at this was the *Upuaut* project carried out by Rudolf Gantenbrink between 1992 and 1993.[607] Four scientific exploration robots, with capabilities including motion, transmission of images and precise measurement functions, were applied in a study of shafts in the Great Pyramid of Cheops. In 2002, the Great Pyramid was studied with another robot, the *Pyramid Rover*, produced especially for this purpose by the **iRobot** company.[608] This robot not only traversed one of the shafts in the pyramid, but also made a three-quarter inch hole in a two inch thick blocking stone at the end of the shaft to study what lay beyond it, revealing another slab.

603 Data for year 2002, published in *World Robotics 2003 – Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment* (United Nations Publications), ISBN 92-1-101059-4, Press release online at http://www.unece.org/press/pr2003/03stat_p01e.pdf

604 http://asl.epfl.ch/aslInternalWeb/ASL/publications/uploadedFiles/WSProceedings.pdf

605 For more detail see Nourbakhsh, I.R., C. Kunz and T. Willeke, 'The Mobot Museum Robot Installations: A Five Year Experiment,' http://www-2.cs.cmu.edu/~illah/PAPERS/Paper69Mobot.pdf

606 http://www.learn.columbia.edu/amheida/html/nsf_project.html#

607 http://www.cheops.org/

608 http://www.irobot.com/industrial/prover.asp

Underwater archaeology is another important area of robotic applications for the cultural heritage sector. Underwater archaeology is difficult for humans and a combination of robotic sensors for discovering objects, cameras to take pictures or video films, arms for handling samples, and the ability to dive very deeply mean that robots are much more suitable than humans for this demanding work. Before the use of robots, no major shipwreck site deeper than 200 feet had ever been investigated. Robert Ballard, famous as the discoverer of the *Titanic*, organised several expeditions to the Black and Mediterranean Seas where ROVs (Remotely Operated Vehicles) such as the *Hercules* were used to study shipwrecks.[609] ROVs have also been used to study the wreck of the USS Arizona, sunk at Pearl Harbor on December 7th, 1941.[610] Researchers from the *Underwater Resources Center* of the **National Park Service** in Santa Fe, New Mexico used a miniature ROV to take pictures inside the ship and to gather scientific data which will assist in its preservation.[611]

Case Studies

The Museum of Pure Form[612]

Funded by the European Commission under the 5th Framework Programme's 'Digital Heritage and Cultural Content' key action area (IST 2000-29580), the **Museum of Pure Form** aimed to explore new paradigms of interaction with sculptural pieces of art and create a virtual gallery featuring three-dimensional digitised sculptures from European and worldwide museums with which visitors could interact with touch and sight. Project development was carried out by a consortium of partners coordinated by **PERCRO** at the **Scuola Superiore Sant'Anna** (Italy), and made up of **University College London** (UK), **3D Scanners Ltd**, Coventry (UK), **Uppsala Universitet** (Sweden), **Pont-Tech**, Pisa (Italy), **Centro Gallego de Arte Contemporáneo** (Galician Centre for Contemporary Arts), Santiago de Compostela (Spain), and the **Museo dell'Opera del Duomo**, Pisa (Italy). Other associate museums that have contributed to enrich the digital collection of works of art are the Conservation Centre at **National Museums, Liverpool** (UK), the **National Museum of Fine Arts**, Stockholm (Sweden), and the **Petrie Museum of Egyptian Archaeology**, London (UK).[613] The Pure Form project began in September 2000, and was funded for 36 months. The project's total budget is €1,723,199, with EC funding of €1,599,997 and a total manpower of 225 person-months.

Haptic perception represents the most immediate and intimate way of interacting with

609 Produced by Woods Hole Marine Systems, Inc., http://www.whmsi.com; HERCULES specification is on http://www.whmsi.com/HERCULES.htm

610 http://www.cnn.com/2003/US/12/06/USS.arizona/index.html; image available at http://www.videoray.com/Products/Images/vrhatch.jpg (Title: VideoRay entering USS Arizona with National Park Service diver Matthew Russell. Photo credit: USS Arizona Memorial; NPS Photo by Brett Seymour; Submerged Resources Center; National Park Service)

611 http://www.videoray.com

612 This case study is based on an email questionnaire completed in March/April 2004 by Massimo Bergamasco and Antonio Frisoli of the **Scuola Superiore Sant'Anna**, and on materials available on the Web. http://www.pureform.org/; http://www-percro.sssup.it/projects/pureform.html

613 http://www.percro.org/; http://www.ucl.ac.uk/; http://www.3dscanners.com/; http://www.uu.se/; http://www.pont-tech.it/; http://www.cgac.org/; http://www.opapisa.it/index.html; http://www.liverpoolmuseums.org.uk/; http://www.nationalmuseum.se; http://www.petrie.ucl.ac.uk/

sculptures and other art objects, allowing the observer to perceive the concept of space the artist has impressed on the art forms during their formation. For reasons of security and preservation, visitors to traditional museums may only observe the objects and, since touching is not permitted, this experience falls short of a full appreciation of the artistic value and intrinsic beauty of the collections. Moreover, the appreciation of visual art is often denied entirely to blind and visually impaired visitors. Through the conjunction of virtual reality (VR) and haptic technologies, the Museum of Pure Form offers an alternative by giving the haptic perception of artistic forms an approximation of the same essential role it had for the artists during their creation. Users can perceive subtle tactile stimuli which equate to the contact of their hands with the digital copy of a real object. The realism of the virtual simulation is increased and integrated by the stereoscopic visualisation of digital models thus giving users the feeling of touching the surface being visualised as its image floats in space before them.

The Museum of Pure Form utilises two core haptic devices to reproduce the sense of touch: an anthropomorphic exoskeleton interface and an external desktop device. The exoskeleton is worn on the operator's arm and is particularly suitable for installations in full immersive Virtual Reality environments since the bulk of the device is worn on the operator's arm. Thus the device does not occlude the view of the virtual scene and does not disturb the perception of the 3D effect generated by the vision of two polarised images for the left and right eyes.

The exoskeleton is itself composed of two sub-systems: the Light-Exos (LE), and the Pure-Form Hand-Exoskeleton (PFHE). The LE is a wearable afferent-efferent robotic device which allows the user to experience direct interaction with a VR system. Its mechanism includes both sensors and actuators, allowing it to track the arm position and exert the appropriate forces on it. The LE can be mounted on a mobile support giving the user more freedom of movement. The PFHE is a portable haptic interface designed to exert forces of direction and amplitude on the tips of the index finger and thumb. Coupled together the two systems can exert forces independently on the two digits combining the greater workspace of the arm exoskeleton with the higher performance capabilities of the hand exoskeleton.

The Pure Form desktop device is operated by the fingertips of the user's hand via thimbles that can be worn either on two fingers of the same hand or a finger of each hand. Two distinct robotic arms protrude from support columns placed in front of the visualisation screen and the visitor can easily interact with the digital models. The workspace covered by the two robotic arms is large enough to allow the user's arms complete mobility and a workable degree of interactivity.

One of the project's primary objectives has been to evaluate the efficacy of haptic technologies for presenting 3D content to the public, in particular digital copies of sculptures. An early user requirements analysis was conducted to determine the characteristics of the devices, e.g. the number of contact points necessary for the haptic interface. The results of other haptic projects in the cultural heritage and other fields were analysed by **PERCRO** and **University College, London** and these were taken into account during the development of the technologies. Before the project began, there were few publications on this specific application and some of the observations acquired during the Pure Form project will provide an evaluation about the capability of the adopted technology and criteria for improvement and design of new devices. The ideas generated by the project are leading to the conception of simplified tactile devices capable of overcoming some of the limitations found in contemporary technology.

The development of the haptic components drew on the expertise of a variety of disciplines. Robotics experts, including mechanical, electrical, control and software engineers, worked in close contact with architects, software developers and experts in 3D scanning and computer graphics. All of this work was planned and reviewed with experts of perception and psychophysics, psychology, history of arts, communications experts and museum curators. The consortium was composed of partners with real complementary skills. **PERCRO**, **Pont-Tech** and **3D Scanners** carried out the scanning operations and post-processing of the models, while **PERCRO**, **Pont-Tech**, and **University College, London** dealt with design and presentation of the virtual gallery.

The digital sculptural models were derived through the laser scanning of real sculptures. A portable non-contact laser scanner, mounted on an articulated robot arm was moved around the sculpture to acquire the geometric data. This did not necessitate touching the sculpture in any way. The scanner head observed the deformation of a laser beam projected on the object and estimated with high precision the geometry of the sculpture. After the scanning, a cloud of points lying on the surface of the sculpture was generated from which specific algorithms were employed to extract a regular polygonal mesh with a reduced number of polygons. In fact, as the mesh extraction phase produced models composed of several million triangles, too many to be successfully handled by computer graphics applications, a reduction operation was used to obtain simplified meshes suitable for effective graphical and haptic rendering.

It should be noted that the haptic models are also designed to work with other haptic devices including commercially available devices like the PHANToM. The software library that has been developed is compatible with all devices supported by the GHOST SDK. The way in which the software architecture has been conceived allows the easy addition of support for devices other then PERCRO's own.

The development of the complete exoskeleton system was carried out by a team of twelve engineers coordinated by three senior engineers and organised into three groups specialising in mechanical design, electronics and control. The support of two technicians was needed for the integration and the electronic cabling of all the parts. The actual construction of almost all the parts and components of the haptic interface system was performed by highly specialised machinists. The total cost of the development, including personnel costs, was approximately €400,000.

The Museum of Pure Form has had a number of deployments in cultural heritage institutions across Europe. In September 2003 a new multimedia room was opened within the **Museo dell'Opera del Duomo**, Pisa, and the Museum of Pure Form was first presented to the public. Visitors entering the room were immersed in a quiet atmosphere with suffused lights and soft music. A stereoscopic 3D projection of a virtual environment was projected on one wall and visitors were free to interact with the contents of the environment through the attached haptic interface system. An audio narration provided the visitor with historical information and details about the works on display.

The Museum is intended to work with a variety of display technologies and its first deployment within a CAVE-like environment was held at **University College, London** in November 2003. Visitors were able to navigate their way through the simulated museum, select a specific sculpture and interact with it. The interaction with the selected sculptures was obtained through the CAVE interface and the force-feedback arm exoskeleton. This provided an extremely high level of realism, giving users the feeling of touching the surface being visualised and placed in the space under their own hands.

In early 2004, a three-day event was held during the opening of the Pure Form

Exhibition at the **Centro Gallego de Arte Contemporanea**, Santiago de Compostela, Spain. The event featured seminars from invited speakers on the theme of 'Novel technological interfaces for the perception and enjoyment of works of arts: background, current situation and perspectives.' Participants included the artists Marcel lí Antúnez, Ken Rinaldo, and Stelarc, and **Media Centre d'Art i Disseny** (MECAD) director Claudia Giannetti, discussions covered different trends in the use of interfaces such as electromechanical prosthetics, exoskeletons and sensor systems, from both a theoretical and a practical point of view. The Pure Form system was exhibited throughout February with encouraging results in terms of public enthusiasm and user's satisfaction. With an opening schedule of three days per week, more than 400 users explored the potential of haptic interfaces for engagement with artworks.

While computer graphics and visualisation technologies have reached a fairly mature state of development, haptic technology is still considered to be in its infancy. The Pure Form project has provided important indications for the improvement of haptic interfaces in performing shape recognition of digital 3D forms. Haptics offer new ways for presenting sculptures to the public, inviting people to spend more time around a work of art, observing and appreciating aspects such as shape, texture and other details which may otherwise be missed. A simultaneous audio narration with synchronised images can provide an explanation of the relevant features of each work, explaining the author's choices and situating the work in its historical period or movement.

Formal evaluation of the project took place at **University College, London** in November 2003, where several experiments on the sense of presence were conducted using the Haptic Interface system in a CAVE environment. This has continued at **CGAC** and at the Swedish **Nationalmuseum** during the first three months of 2004. In collaboration with the **Interactive Institute**[614] and the **Nationalmuseum**, a further evaluation was conducted in the context of the 'False and Genuine' exhibition which concerned the verification of originals against copies, replicas, forgeries, pastiches, paraphrases and plagiarisms. The Pure Form systems were used to evaluate the potential of haptics as a means for creating virtual copies of sculptures and in answering the question: "Is it possible to have a virtual copy of a real sculpture?"[615] Visitors were asked to compare their experiences of several copies of a sculpture by Johan Tobias Sergel made of different materials, including plaster, terracotta, and even chocolate, together with the haptic model produced by the Pure Form project.[616]

Results from the preliminary evaluation carried out in Spain and Sweden indicate positive public reaction to the systems. In Santiago de Compostela, more than 90% of visitors described the Museum of Pure Form either as amusing or instructive, confirming the value of the installation as a means of *edutainment*. In addition, 95% of visitors expressed a wish to see similar installations in other museums. An obvious drawback is the lack of widespread public access to haptic devices needed to experience the models. To overcome this, the project coordinator intends to transform it into an itinerant exhibition travelling around European museums. The **Centro per l'Arte Contemporanea Luigi Pecci** in Prato was due to host a temporary exhibition of the Museum of Pure Form in September 2004.[617]

614 http://w3.tii.se/
615 More information can be found at http://www.nationalmuseum.se/NMTemplates/NMSingleExhibition____3122.aspx
616 Results of this evaluation were not yet available at the time of writing.
617 http://www.museopecci.it/

The Pure Form team believes that haptics can involve people more directly in museum multimedia installations. Haptics demand interaction and can help visitors focus attention on specific aspects of presented works. Knowledge learnt by interaction, involvement and participation differs from that which is acquired passively and the active acquisition of knowledge can substantially improve the quality of information that is learnt.

Avatar Body Collision[618]

© Avatar Body Collision

Lagging with the Lololols

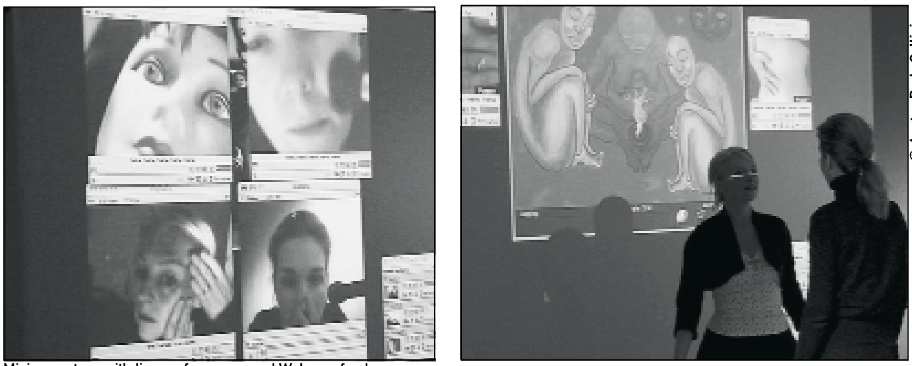
In their own words, **Avatar Body Collision** (ABC) is a "collaborative, globally distributed performance troupe," with members currently based in England, Finland, New Zealand and Serbia. Each member has her own interests and tasks: Helen Varley Jamieson has a background in theatre as a writer, director and producer, and has worked in digital media and the Internet since 1996; Karla Ptacek's work spans two decades in New York City as performer, writer and director in multimedia ensembles; Leena Saarinen is a new media arts and information technology graduate, embarking on a doctorate in computer mediated communication; and Vicki Smith is a visual artist working in design for both print and the Web. The group's collaborative projects include *Lagging with the Lololols*, an investigation into "distributed practices of goddess worship in extreme Internet cultures," *s w i m,* "an exercise in remote intimacy," the theatrical anti-war protest *Dress The Nation*, and "comic book techno-noir" *Screen Save Her.*

The ABC team stage *cyberformances* on the Web, blurring the boundaries between live performance, multimedia and cyberspace. The means for achieving these effects include 2D graphic-sonic chat and Webcam conferencing. Upcoming projects will use mobile communications devices and protocols to "extend… performative mobility and include a street spectatorship".[619] The Colliders meet, plan and rehearse in *the Palace*, a piece of free client-based software which allows real-time chat, avatar movements, sound effects and more.[620] Each 'palace' consists of a number of rooms linked by clickable areas. Each room can be used for a different purpose and may have different properties. Some, for example, contain scripting to alter the text of user conversations thus altering the normal relationships between collaborators. Scripting can also be used to produce set dialogues, sound effects, backdrops and events, enabling a more animated movement process. These features are used in the group's online performances.

Multiple avatars can be used to suggest animation and movement but it is difficult to type dialogue and control an avatar at the same time. Leena Saarinen is the group's chief scripter and arranges scripts so that a trigger word can set off a series of events allowing the actors to concentrate their energies (and digits) on controlling their avatars and, perhaps simultaneously, acting to camera.

618 This case study is based on Palace interaction between Karla Ptacek of Avatar Body Collision and Martin Donnelly of DigiCULT on 24/03/04. Avatar Body Collision: http://www.avatarbodycollision.org
619 http://www.avatarbodycollision.org/about.html
620 Palace software is downloadable from http://www.thepalace.com/

Texts and conversations can be converted to speech automatically. Typed 'speech' can take different forms – straight dialogue, thought bubbles, shouting and whispering (whereby only a selected person can hear what is being said). Avatars can be named or nameless just as palaces can be public or private, so the level of intimacy can be controlled according to purpose.



Mixing avatars with live performance and Webcam feeds

These systems have limitations and the team has recently developed its own Web-based venue for live, real-time cyberformances. Designed and built by the ABC team in conjunction with New Zealand software designer and artist Douglas Bagnall, *UpStage* allows artists to bring together different digital media types such as Webcams, graphical avatars, text chat and audio, enabling a live performance which can be viewed and joined by online audiences.[621]

UpStage is open-source software and is free to download. Its development was funded through the *Smash Palace Collaboration Fund*, a joint initiative of **Creative New Zealand** and the NZ **Ministry of Science, Research and Technology** with the support of **MediaLab South Pacific**.[622] The software uses *Twisted* and *Python* on the server side and **Macromedia** *Shockwave* and *Flash* for the client.[623] Communications between clients and server are managed by plain TCP sockets. Written in *Python, Twisted* is a framework suited to creating event driven network applications such as UpStage. The server-side also makes use of *Gstreamer* for video, *Ming* for Shockwave/Flash processing, and the *Festival* speech synthesis system for text-to-speech.[624]

UpStage was launched in January 2004, and since then the **Avatar Body Collision** team has held a series of walk-throughs to give viewers an idea of how UpStage works from the perspective of the actor. In order to view an online performance, users simply to point their browser to the UpStage Web site at the appointed time and can then watch and participate to various degrees determined by their user privileges.[625]

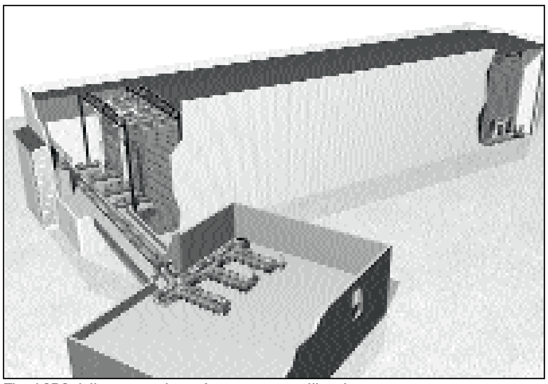
621 http://www.upstage.org.nz/
622 http://www.creativenz.govt.nz; http://www.morst.govt.nz; http://www.medialab.co.nz
623 http://www.twistedmatrix.com/products/twisted; http://www.python.org/; http://www.macromedia.com/software/
624 http://gstreamer.freedesktop.org/; http://ming.sourceforge.net/; http://www.cstr.ed.ac.uk/projects/festival/
625 For another account of telepresence in performance see Maria Beatriz de Mederios, 'Performance Art in Telepresence: Information and Communication in the World Net of Computers'

Nasjonalbiblioteket, *Transitio* project[626]


© Nasjonalbiblioteket
Inside the ASRS

The **Nasjonalbiblioteket** is Norway's National Library with premises in the capital, Oslo, and Mo i Rana in the north of the country just below the Arctic Circle. A repository library was established in Rana in 1990 to house a document redistribution service of old and infrequently-accessed material from a centralised storage system in order to contribute to a more efficient use of resources in the Norwegian library system. Demand for publications at the repository library has exceeded all expectations. Each year it lends some 60,000 publications and has assumed a central role in collecting and cataloguing surplus library books, making them available through inter-library loans. The repository library holds collections of Norwegian publications deposited through the Statutory Deposit Act as well as a number of publications transferred from other libraries.[627] The collection boasts some 800,000 books and periodicals all of which are catalogued in the Norwegian bibliographic cataloguing system **BIBSYS**.[628]

The **Transitio** project started in January 2002, and ran for 18 months as part of the larger *DEPOT II* project. The motivation for an automated library system began in 1995 when the repository library was issued with a new stack incorporating compact mobile shelving. Due to the unexpected popularity of the repository library, by the time the mobile shelving was ready to use, its capacity was already too small and the library was forced to store a huge amount of material in various places until the storage problem was solved on a permanent basis. The introduction of an ASRS was first suggested in 1996. As **Transitio** project manager Kari Mathisen explains: "Rana is an industrial society and many of the library's employees (including some Heads of Department) are former industrial workers. The merging of industrial and librarian cultures provided an environment for the development of ASRS instead of traditional storage systems. Four years later the planning and preparation was able to begin."


© Swisslog
The ASRS delivers containers from storage to librarians

Transitio links two distinct systems: a library management system (LMS) supplied by **BIBSYS** and a *Warehouse Management System (WMS)* which controls the ASRS

626 This case study is based on an email interview with Kari Mathisen, project manager of the Transitio project, carried out on 06/04/04. http://www.nb.no/

627 The Repository Library also administers the Norwegian newspaper collection, a nearly complete series of newspapers dating back to 1763, consisting of originals and microfilm copies. http://www.depotbibliotek.no/

628 As well the National Library, BIBSYS services are used by all Norwegian University Libraries, all college libraries, and a number of research libraries in the country. http://www.bibsys.no/

and is supplied by **Swisslog**.[629] These two systems communicate with each other and send reports of information back and forth so the other system knows what to do, for instance, when orders arrive or new books need to be loaded into the ASRS. The steering system which handles the ASRS controls the transport and storage of units, consisting of steel boxes with materials in hanging folders and a maximum weight of 36kg. Robots running on rails between the stacks retrieve the individual storage boxes. The system also handles instructions which are being sent electronically to the *WMS*, ensuring the automatic and secure running of the ASRS. The *WMS* communicates with the *CraneBox* and the *Conveyor*, the two main systems that run the robots and the rail system. There are other minor systems which fulfil specific functions. A programme called *Palsta* creates transport missions and is the brains behind the movement of the containers.

A database process called *Find_Loc* is responsible for choosing which crane entrance the boxes should go to and for locating the exact position in the rack. The LMS sends orders based on barcodes on the units. These orders arrive at three different pick-up stations and operators are told from which folder to collect a certain book, periodical or microfilm. The PCs communicate using a standard *Windows* server/client architecture and *Oracle* program ware.

The *WMS* directs and administers all functions connected to the ASRS. This includes the receipt of boxes from *Intrack* and *Pick-up* stations which are operated manually by staff. The staff also use hand scanners to recognise the boxes by means of barcodes. The *WMS* communicates with a **Swisslog** product called *CraneBox* which is responsible for transport of the steel boxes in the ASRS. On the instructions of the *WMS*, *CraneBox* executes the transport of boxes out and in and reports back to the *WMS* when the mission is completed. The pick-up of units from boxes during the fulfilling of orders is optimised by the *WMS* but can be handled manually. The system can perform various operations at the same time, for instance, handling the orders both in and out of the ASRS . When a book is picked up from a folder, a similar book is selected to be returned into the ASRS thus keeping the box weights roughly the same. The *WMS* also maintains the database, visualises the transport system and communicates with the steering programme PLC responsible for controlling the rail system.

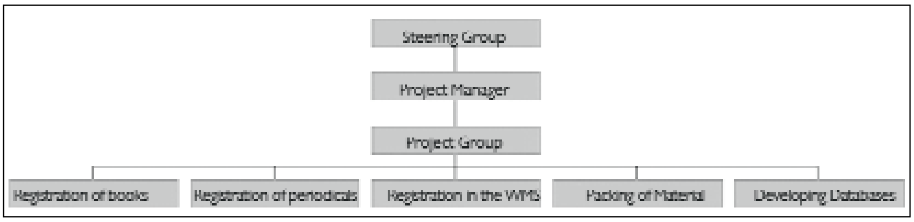
The logistics of introducing the system were complicated with a wide range of tasks needing to be completed. The publications were housed in three different buildings and, during the process, over one million publications had to be moved several times. These publications were labelled and placed in folders in the ASRS storage boxes. These boxes were in turn placed on the fourteen-meter high stacks in the ASRS building. The work was done by the repository librarians assisted by five workers hired in for the duration of the project. Thus, a total of thirty staff members were involved in the deployment, including the project manager and Head of Department. Prior to the system's development, a group of **Nasjonalbiblioteket** staff members visited similar ASRSs in university libraries in Europe and in the USA: **Biblioteka Slaska**, Katowice, Poland; **Bibliothèque de Bordeaux**, France; and the Jean and Charles Schulz Information Centre at **Sonoma State University**, USA.[630]

629 http://www.swisslog.com/
630 http://www.bs.katowice.pl/; http://www.mairie-bordeaux.fr/bibliotheque/bibintro.htm; http://libweb.sonoma.edu/about/ars.html

The budget for the Transitio project was 10,383,762 NOK (€1,238,087). This included both human and technical resources. The local staff were already capable of handling standard librarian tasks such as registering new material and scanning documents into the *WMS*. For more technical and complicated problems, three members of staff received special training in order to handle the ASRS as 'superusers.' As project manager, Mathisen was responsible for the communication and problem solving between the two system contractors, **BIBSYS** and **Swisslog**, and **Statsbygg**, the Norwegian Directorate of Public Construction Property.[631] **Statsbygg** was very strict about the development of the ASRS, ensuring that it met demands concerning the required system functionality.

The new ASRS building

The project was organised hierarchically with a number of working groups at the bottom:



Each group reported to the project manager on a fortnightly basis and at the end of each month she made a report based on the results achieved and on statistics collected from the *BIBSYS* and *WMS* databases.

The ASRS has had a number of benefits for the Library. It offers a tremendous chance to develop and control the collection in an easier, better way than before when many routines were handled manually. Because the system has been in place for just a short time, the full range of benefits are not yet known but Mathisen's advice to anyone considering the introduction of such a system is to make routines and operations as easy and plain as possible.

Transitio has reached the goals which were set out in the project description. However, some problems were experienced during the testing period with the communication between the two systems involved. There were also some mechanical, technical and data problems within the ASRS, which **Swisslog** and rail system contractor **Univeyor** worked together to solve.[632] The focus is now on running the *LMS* and *WMS*. In earlier days, when manual routines were used for handling the collection and orders, there was no need for that type of work. The ASRS has been found to be much cheaper than traditional storage methods both in terms of the initial investment and for its ongoing running costs. Library staff have held discussions regarding future service plans and support from **Swisslog** but no decisions have yet been made. It may be a d vantageous to make the system dynamic so that it is able to change according to the demands from the sur-

631 http://www.statsbygg.no/
632 http://www.univeyor.dk/

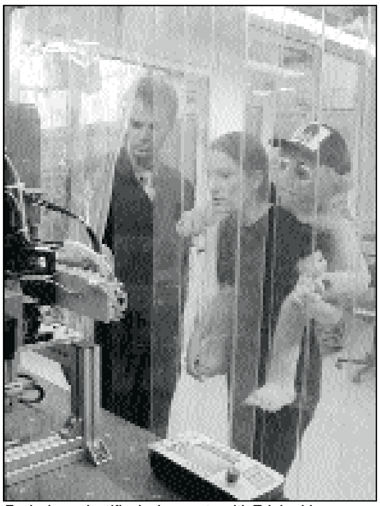
roundings and environment. The systems must also be flexible in response to user needs. For instance, if the repository library is to take on further responsibilities concerning storage of other collections or developing other types of services, increased flexibility will be essential.

Telebuddy[633]

There are always many more events taking place worldwide than we can possibly attend. Internet streaming allows Web users to see and hear concerts on the other side of the world but the participatory element is lost along the phone lines. This problem extends to cultural institutions. Few of us can afford to travel the globe, visiting and experiencing guided tours of the famous galleries and museums. The *Telebuddy* project aims to provide remote visitors with a sense of interaction in distant locations via telepresence allowing them a form of physical interaction. Users operate a *Telebuddy* puppet via the Internet to see, hear and speak through their physical representative carried on the back of a real-life visitor in the remote location.

The project team was interdisciplinary and highly cooperative. Three staff members dealt with the interactive component design, i.e. the puppet itself and the Internet platform. Two more staff members dealt with the incorporation of robotic elements within the puppet and a team of four created the technical elements, i.e. the software architecture, hardware concept and dialogue manager.

On the client side, *Telebuddy* utilises HTML Pages and a Java applet with input received via the keyboard and output delivered via a live video stream and speakers/headphones. The main server runs *Apache/Tomcat* with *Darwin* or *Real* as the streaming server, together with a video archive containing recorded videos of past events. The physical *Telebuddy* avatar resembles a puppet and has audio output with mechanics for gestures (indicating that the puppet is about to speak), sensors to specify the buddy's current position in the exhibition, a camera and a microphone. On the local PC, text-to-speech software is used to allow the buddy to 'speak' on the remote user's behalf along with mimic control software which allows the puppet to signal to its carrier. *Cisco* and *Real* are used for video and audio streaming. The buddy has built-in modem coding capabilities allowing output transferred direct to the Web. Its integral display allows the carrier to read instructions from the Web users. *IrDA* infrared beacons provide the system with spatial information regarding objects or exhibits.[634]



Exploring scientific deployments with Telebuddy

As with any communications technology, telepresence is potentially subject to abuse. The designers initially considered giving *Telebuddy*'s real-life carrier the duties of moderator screening the questions and comments coming from the Internet, vetoing inappropriate mate-

633 This case study is based on an email interview with Anja Hoffmann of the **Zentrum für Graphische Datenverarbeitung** (ZGDV e.V.), conducted over a period of months in early-to-mid 2004. http://www.telebuddy.de/

634 http://www.igd-r.fraunhofer.de/IGD/Abteilungen/AR3/Projekte_AR3/IrDA/index_html

rial before it had a chance to be spoken. It was felt, however, that this might compromise the user's feeling of presence. The team therefore implemented a functionality called *collective awareness* through which users submit questions via the Web site and the user community votes them good or bad. Only those questions approved by the community are forwarded to the puppet.[635]

The *Telebuddy* was unveiled at the *EXPO 2000* world's fair in Hanover, Germany, and was first presented at the "Science and Technology: Thinking the Future" session between July 11th and 13th, 2000. Another *Telebuddy* was simultaneously located at the **Institut für Werkzeugmaschinen und Betriebswissenschaften** (Institute for Machine Tools and Industrial Management) in Garching, Germany, allowing Internet users to visit exhibitions and laboratories there via live broadcasts.[636]

Telebuddy's primary innovation is its simple mobility. Cheaper and easier to build and maintain than a robot, the puppet represents a straightforward and ingenious solution to an age-old problem: the need to be in two places at the same time. The project has been considered a great success, attracting significant media attention. User reactions tended to be positive with most finding the project curious, unusual and entertaining. There is potential for *Telebuddy* to be deployed as a tourist guide system. For instance, the puppet could join a group at an archaeological site in the remote west of Ireland with Internet users from all over the world logging on and interacting via telepresence.

Telebuddy in use at EXPO

The project was funded by Germany's **Bundesministerium für Bildung und Forschung** (Federal Ministry for Education and Research).[637] It was a cooperation between **ZGDV e.V.** (the Computer Graphics Centre) in Darmstadt, and the **Fraunhofer Institute for Computer Graphics** in Rostock, both Germany.[638] The project ran between November 1999 and June 2001.

Scenarios

A robot for mapping indoor locations – providing online floor plans and learning tools

A city museum has as part of its collections a large number of items related to Victorian archaeological digs. Displays feature discovered objects (such as ceramic bowls) alongside examples of the equipment and methods used by archaeologists from Victorian times to the present day including excavation diaries, the scientific equipment used during the excavation (e.g. measuring tools and early cameras) and personal possessions.

While the museum plans developments to its interior layout, it becomes clear that

635 Needless to say, the functionality for spontaneous comments is still in place, and can be switched off and on as necessary.

636 http://www.iwb.tum.de/

637 http://www.bmbf.de/

638 http://www.zgdv.de/zgdv; http://www.igd.fhg.de/index.html

accurate floor plans are required both for administrative reasons (such as providing emergency exits) and for arranging future exhibitions. One of the archaeology specialists points out that contemporary archaeologists sometimes use robots to create accurate plans of the interiors of structures such as tombs. Other staff members are initially sceptical of the financial feasibility of using a robot for this task but the specialist proposes a valuable way to incorporate the robot into the museum's permanent collection. Based on the understanding that visitors are interested in archaeological methods as well as its results, he suggests a new exhibition, titled "Archaeology: Then & Now." The exhibition will present the equipment and techniques used by archaeologists over the last century showing the scientific and technological progress in the field as well as artefacts recovered from digs. The robot will be used to demonstrate modern techniques in mapping an underground site, repetitively measuring out an area (constructed with a cut-away wall to allow visitors to see) and sending the data to a display workstation.

The museum contacts a local university for help in buying and adapting a small robot. Then, in conjunction with research staff from departments of archaeology, computing science and electrical engineering, the robot is used to produce accurate floor plans for each of the museum's three levels.

The floor plans are used to assist in designing the new layout and the museum archives them in both digital and paper form with a view to using them when future changes are being planned. The staff also come up with a way to use the plans to benefit the visitors more directly. Images showing the museum's new exhibition layout are produced, uploaded to networked kiosks within the museum and linked to photographs of artefacts and background material. The museum has existing QuickTime object movies of some of its displays which can be linked to appropriate sections of a map. Low-resolution versions are made available on the Web site enhancing the museum's virtual presence and attractiveness to online visitors.

The specialist's proposal for including the robot in a permanent exhibition is implemented with a few minor modifications. A timeline is created focussing on five excavations from the past hundred years. It treats equipment as important artefacts and gives information on the methods used to inform understanding of the unearthed objects. For the most modern excavation, a false 'tomb' is constructed and the robot is set to work creating accurate measurements. Further functionality is implemented in the shape of a virtual 'kids' where younger visitors are encouraged to "rearrange" the exhibits on the virtual floor plan via a simple, drag-and-drop interface. Users can then submit their alternative arrangements to the museum staff who uses these sometimes far-out ideas to inform the institution's child-friendliness. The drag-and-drop interface has a dual function. While it is fun for the visitors, it is also powerful enough to act as a kind of market research tool for curators when organising exhibitions and new permanent displays.

The staff is extremely pleased with the new exhibition, acknowledging the fact that the importance of archaeological methods had previously been under-exploited in the displays. It also proves to be extremely popular with visitors, inciting many questions and much positive feedback. There are a few teething problems while staff members familiarise themselves with the robotic technology but after six months the number of critical failures is very low with the robot only requiring human intervention to charge its batteries at the end of the day.

Haptic manipulation of fragile fossils

A natural heritage centre with expansive visiting space specialises in prehistory. It receives much of its business from school trips and parent/child groups with a strong interest in dinosaurs. The centre is also home to a small research facility for the study of fossils and holds an impressive collection of fossils from many prehistoric periods. A considerable number of common fossils are available to touch and manipulate but larger and more finely detailed fossils are rare and fragile and are, therefore, unsuitable for handling in an uncontrolled environment.

The centre manager has seen haptic devices in use at his local science museum and, having had first hand experience of the way in which young children exploit their sense of touch in investigative learning, he starts to look into the possibilities for using this technology in his own organisation. He examines the uses of haptics across a range of disciplines from veterinary medicine to space exploration and an idea begins to take shape.

After putting together a detailed proposal, the centre is awarded a grant from a public funding body to implement the haptic fossil display. The first step is to map the most impressive fossils into haptic data. The centre manager out-sources this task to a company specialising in object modelling for haptic reconstruction. The company has experience in converting very valuable and fragile objects and is able to assure the centre's staff that the process would not damage the fossils. It recommends a commercial haptic device, *PHANToM*, which will allow users to experience the size, weight, hardness and texture of the rarer fossils first-hand. After the objects are modelled, the staff test the haptic interface and are satisfied with the results. Now, staff also wants to use the technology to create further functionality which could not hitherto be achieved.

Borrowing the idea of casting fossils to produce models, the centre manager asks the company to produce a 'negative' of the haptic data, i.e. a haptic model of the creature or object which made the impression. As the data have already been captured, it is easy and inexpensive to produce the negatives using a simple algorithm, creating digital models from fossils too fragile to cast in more traditional ways. Many of the objects are fossilised small creatures so, after consulting an expert on prehistoric fauna, the centre manager asks the company to include a very simple movement into the haptic models, for example, the fluttering of a dragonfly's wings.

At the same time, the centre employs a programmer to design and implement a simple interface for accessing the haptic models. After discussion with the staff and observation of visitors, the programmer produces a simple interface with which users can select a model from a touch-screen monitor and use the *PHANToM* device to 'feel' it. The system can be operated by one person but designed for group use with one user choosing the model and another operating the haptic device. The programmer also includes a simple 'guessing game' where the computer selects a model at random and the users identify it.

Initial testing and evaluation of the system shows that users react intuitively to the interface and really enjoy 'feeling' the haptic models. The moving models are particularly effective, as confirmed by shrieks of horror and delight from children and adults as they feel the creatures squirming under their fingers. However, the expensive equipment is not robust enough for unsupervised use so the centre manager commissions a special housing which still allows a full range of movement whilst protecting the delicate machinery.

To promote the visitors' centre and the research facility, the haptic representations are later made available for delivery via the Web. While the haptic models can only be experienced by users with the appropriate hardware, the manager finds (from submitted feedback forms) that real-life visits to the centre as well as virtual visits to the Web site increase as a result of the innovative new addition. The haptic fossils are found to be especially popular with blind and partially sighted users. Schools from all over the world log on to allow their students to access and experience these artefacts in a convenient and natural way.

Telepresence and a virtual musical performance

As part of a cultural exchange scheme, groups of musicians from Europe, Africa and Asia are seeking new ways of collaboration and cross-fertilising ideas and musical modes. The project involves individual musicians from the participating countries as well as major recording studios based usually in larger cities. The project lasts over a year and the expense involved in frequent travelling between their respective continents is more than the arts council grant can sustain, causing the project to begin to falter in its early stages.

The project leader begins to seek ways of maintaining live contact between participants in order to maximise collaboration time in the build up to face-to-face recording sessions. She looks into the use of virtual private networks (VPNs), content distribution networks used in the broadcasting industry and personal networks for small numbers of users. With the technical expertise of recording studios, the project leader establishes broadband *Webcam* linkups between participating studios, requiring musicians to travel only within their own countries in order to collaborate with their distant counterparts. The network is private to its participants and the studios and service providers ensure that data transfer between sites is secure. Some of the project budget is used to invest in state-of-the-art hardware which results in an almost negligible network time lag. The musicians agree to collaborate over the period of the project with regular 'rehearsals' over the VPN culminating in a week of intensive playing. Of course, there is no substitute for the sounds which can be created by musicians playing together in the same room and traditional recording sessions are later arranged which draw heavily upon (and expand) the rapport built up during the rehearsals on the telepresence linkups. In fact, the speed and ease of the recording sessions exceeds all expectations and participants are delighted with the resulting music.

The recordings are released commercially and are financially successful, providing royalties for the musicians. As a postscript to the collaboration, a real-time performance is put on using telepresence with musicians from three continents playing in real-time harmony across cyberspace. This event is well publicised and generates a great deal of interest both in the music and in the means by which it was composed and arranged.

After the project's evaluation, the initial funding body decides to support more projects using telepresence to achieve similar collaborations. The project's leader and one of the continental co-ordinators create a scheme improving access to musical instruments for children and deprived communities. Some of the musicians from the original team reassemble to participate in this project, whilst others combine their musical abilities and new technological expertise in projects of their own.

Education and design: sculpting with a haptic interface

A school offers a design course which results in a practical qualification. The course introduces the teenage students to theoretical principles of design but its main focus is on practical skills like technical drawing and the use of new technologies. The school's computer lab has some of its workstations equipped with computer-based design packages of various kinds (simple computer aided design (CAD), computer aided modelling (CAM) and VR applications).

However, a repeated stumbling block for students is the difficulty involved in learning to use the software packages. Feedback indicates that students get frustrated at the lack of direct interaction when using input and output devices and with the steep learning curves required to master the processes. The course director believes that the difficulty of translating their conceptual designs into digital form is impeding the students' creativity.

Part of the course content focuses on new technologies to facilitate design, in particular the growing use of 3D input and output devices within the industry. The course director therefore decides to incorporate a trip a state-of-the-art digital design studio which uses haptic interfaces to design and shape its products. The CAD package in use at the studio is **SensAble**'s *FreeForm* haptic modelling system.[639] The package works by displaying a 3D representation of a polygonal mesh and representing it haptically through a force-feedback device. This 3D mesh can be interactively manipulated using *FreeForm* as an input device and the visual and haptic output is updated with any changes.

Workers at the design studio introduce the technology to the students (who are already familiar with the basic principles from their classes). After a demonstration and a few hours' practice, the students generally find the interface more natural than the standard WYSIWYG (What You See Is What You Get) environment with which they are familiar. Using a system such as this has been described as sculpting with digital clay, a metaphor which both enthuses the students and emphasises the advantages of being able to directly 'get a feel' for the object being created.[640]

Prior to their visit, the students have been working on a design assignment including much preparatory research and brainstorming of possible solutions. To best use their time at the studio, they work in groups to produce mesh models of their own design. These are then saved and used to produce prototypes using modern 3D printing techniques and all the prototypes are posted to the design department within a week. The pupils continue their design assignment, moving on to testing, evaluation and refining of the design, and the prototypes become a useful part of the design process as well as a tangible reminder of the visit.

The schoolteachers are heartened by the enthusiasm shown by their pupils and decide to investigate the possibilities of the school investing in haptic design interfaces and 3D printing hardware for the art and design department. The pupils are themselves pleased with this addition to the course and the school's reputation as a centre of excellence in design continues to grow.[641]

639 See Sener *et al.*, "Incorporating the FreeForm Haptic Modelling System into New Product Design" for an in-depth analysis of this package in industry.

640 See also McDonnell, K.T., H. Qin and R.A. Wlodarczyk, 'Virtual Clay: A Real-Time Sculpting System with Haptic Toolkits,' http://www.ktmcd.com/ktm-i3d2001.pdf

641 For a real-life example see Shillito, A.M. *et al.* "'Tacitus' Project: Identifying Multi-Sensory Perceptions in Creative 3D Practice for Development of a Haptic Computing System for Applied Artists" http://www.eca.ac.uk/tacitus

Advantages and Disadvantages

Advantages

Tactile study of artefacts (haptics) – This application of haptics technology is a promising means of making popular rare works of arts more widely available. There are two related obstacles to this work: the high costs of 3D scanning and modelling and the high costs of precise haptic devices. Affordable full-hand haptic gloves are some distance into the future but a real sense of complete haptic interaction and immersion can only be obtained using these.

Remote camera options (robotics, telepresence) – Telepresence allows users to position and focus a camera remotely in accordance with their own personal requirements such as distance from the object, angle of observation or colour filteration. In some cases (e.g. ceiling paintings) close study is difficult in the real world. Telepresence is an ideal solution for this, and cameras can be mounted on wires to examine inaccessible work.

Distant study of collections (haptics, telepresence, robotics) – All three technologies enhance access to collections. Not only can institutions be 'visited' at any time of the day or night but physical distance becomes unimportant.

On-site deployment (robotics) – On-site robots are still unusual and may act as an extra attraction for visitors. Welcoming visitors puts robots in a hosting role and moves to make robots as interactive as possible adding a social dimension to their deployment. They can help keep children entertained, allowing parents to concentrate on the exhibits, or guide visitors to less visited areas of the collection.

Labour saving (robotics) – Robots can be used to switch video equipment and dioramas on and off on demand. This frees human staff to concentrate on other tasks. It would also prevent damage to equipment by untrained users and reduce wear and tear from constant use.

Time savings (robotics) – The use of an ASRS dramatically cuts the time it takes to deliver an item from stack storage to the reader particularly when, prior to ASRS deployment, the item would have been stored at on off-site location.

Cost savings (robotics) – In cases when a library or archive is forced to consider the option of building new repositories for their collections, ASRS should lead to reduced costs (see "Introducing the Technology", below.)

Preservation issues (robotics) – Optimal preservation conditions (in terms of temperature, humidity, and light) are easier to meet in an ASRS than in traditional open-stack storage. In the California earthquake of 1994, materials in ASRSs were not displaced; they were protected in their bins while books from open stacks were scattered on the floor. Metal bins may also provide a degree of protection in the event of a fire.

Disadvantages

Potential for distraction (robotics) – Given the novelty value of robots, there may be a danger of visitors concentrating on the robot instead of the collection, defeating the purpose of the venture.

Potential injury to users (robotics) – Robotics used in public spaces are generally autonomous and should be able to avoid colliding with and injuring visitors. However, human curiosity and unpredictability means that this cannot be one hundred per cent ensured.

Changes to visitor behaviour (robotics) – The use of ASRS places a further emphasis on ordering library/archive material via an electronic catalogue. This may cause changes in visitor behaviour as they would be less able to browse the library stacks to choose what they would like to read. Libraries generally use ASRS to store items that are rarely used although this may further lessen usage of these materials.

Delays in data transmission (telepresence) – Broadband coverage is not yet universal and poor connections or slow data transfer rates may lead to user frustration or dissatisfaction with slow and intermittent audio and video streams.

Hygiene issues (haptics) – As with any kind of hardware, haptic devices installed in museums and used by large numbers of visitors may lead to hygiene concerns.

Staff issues (robotics) – ASRS and robots used as museum guides may lead to reductions in staffing requirements in libraries and museums.

Equipment failures (robotics) – All systems fail from time to time. In order to deal with this, dedicated technicians may be required to monitor and fix system malfunctions and to keep to a maximum the time between failures.

Introducing the Technology

Cost Issues

Although the costs of robotics and haptic devices are coming down, the technologies remain expensive. Vendor companies stress the return on investment (ROI) levels that businesses should experience but they are not so easily applicable to the cultural and scientific heritage sector. In industry, the benefits of robots are measured in terms of decreased labour cost, consistently high quality standards and higher productivity. For cultural organisations, the primary factors will be better quality of service and more visitors.

Of all the technologies outlined in this section, the introduction of an ASRS may provide the most easily demonstrable and measurable ROI. Due to space constraints and growing collections, librarians may be forced to consider off-site storage, leading to extra delays in book delivery, additional costs for storage hire or the construction of new buildings. The **Simon Fraser University Library in British Columbia, Canada**, performed a cost analysis on three storage options for its print collections – open stacks shelving, movable aisles compact shelving and an ASRS – which returned some surprising results.[642] The cost of open stacks shelving was estimated at $26,600,000 (€21,833,000) for start-up costs and $590,000 (€484,000) of annual operating costs, giving a total cost over ten years of $32,500,000 (€26,676,000). Movable aisles would involve $20,000,000 (€16,415,000) start-up costs and $320,000 (€263,000) annual costs, with a ten-year cost of $23,200,000 (€19,040,000). An ASRS had $6,068,000 (€4,980,000) start-up costs and $211,000 (€173,000) annual costs, leading to a total cost

642 http://www.lib.sfu.ca/advancement/arc.htm

of $8,170,000 (€6,705,000) over ten years. This is around a quarter of the cost of the more traditional open stacks and a third of the cost of movable aisles. However, extra costs may be incurred with the introduction of a dedicated technician.

The initial costs of robotic installations will include the price of the robots themselves together with any additional components that may be required. There will also be costs involved in organisational changes, introducing the necessary facilities, staff training and installation of the system(s). During deployment, additional costs will be incurred for maintenance and spare parts, utility and power costs and ongoing training and development.

Selecting a Specification and Development Environment

Before introducing telepresence to an institution, a number of questions must be answered satisfactorily to ensure a smooth development and deployment. Such questions will include:

- How much control over the system is necessary? Is it sufficient for the users to observe the scene (tele-observation) or participate in it (telepresence)?
- What degree of presence is necessary? Textual? Visual-textual? Audio-visual? Audio-visual-textual?
- Which parts of the collection are to be presented to the users? Will there be specific areas for observation or should the whole collection be observable? (N.B. The first approach is more suitable for an art gallery, the latter for a museum. The latter case is also likely to necessitate the use of a fully mobile avatar.)
- Is it foreseen that on-site people will take part in the telepresence sessions? Would their role be as guides, visitors or some mixture of the two? Will they be asked to move according to the wishes of the remote visitor, to share their own experience or provide additional information in an expert role?

As a more complicated (and expensive) technology, haptics would be likely to cause more development headaches. Before moving into this new area, decision makers should be clear on the purpose of the venture:

- Which audiences will the haptic devices be targeted to serve? Disabled users? The general public? Experts in a particular field?
- What cognitive, educational or leisure needs should be met for the specific group of users?
- What benefits will the use of haptic devices provide which cannot be met in other ways? How will their use lead to better understandings of the collection?
- What image-capture facilities will be used to create the haptic models? Does the institution have the relevant experience or will external services be required?
- Will the haptic models be used only in-house or will they be accessible via the Internet? In the latter case, it is reasonable to assume that some users will be using lower-quality equipment. Will the models be of an appropriately high standard that low-powered equipment can do them justice?

Introducing robotics into your institution may be just as complex. Questions that will need to be asked before the development or purchase of a robotic system in a cultural institution will include:

- What is the basic impetus behind the introduction of a robot (or robots)? Attraction of visitors? Serving larger groups of people? Controlling equipment? A variety of tasks?
- Does the organisation have a clear view on any conceptual changes that bringing in a robot may imply?
- Will there be a clear policy regarding the use of robotic tour guides as opposed to human ones?
- If the robot is to be mobile, what areas of the museum would it be required to cover? What is the average number of kilometres per day or week that the robot could cover?
- Will the introduction of a robot necessitate the installation of artificial landmarks (sensors) for its orientation?
- Will the use of robots be combined with telepresence applications to allow remote control and exploration? Or will the robot be autonomous with artificial intelligence?
- What is the robots' estimated maximum time between failure (MTBF)? Is this value acceptable taking into account the number of visitors expected to be served by the robot?
- What is the length of its estimated life span?
- What communication means will the robot utilise? Are these suitable for the museum's audience?

Selecting a telepresence environment will be simpler than haptics or robotics: all that is needed is to compile a list of functions that the system must meet and then match these with those on offer. Many telepresence systems are available free of charge in demo format if not the full versions, so developers can experiment with a number of different setups before settling on an eventual winner. There is also no real reason why multiple telepresence systems cannot be used at the same time although care may have to be taken to ensure interoperability of information between systems and platforms.

Technological Infrastructure Issues

The technical implications of introducing these technologies will depend on the complexity of the proposed system. A simple telepresence setup will be well within the capabilities of most computer users whereas haptic calibration and robotic maintenance will require specialised tools and expert.

The programme for implementing these technologies will normally follow the following stages:

1. Preliminary research including a survey of other institutions with similar experience.
2. Definition of goals and requirements.
3. Choice between various alternatives. In robotics one fundamental question is

whether there is a generic robot which meets the particular requirements adequately or whether a bespoke model must be designed and built. The latter case will usually cost more but unique functionalities may be crucial for specific tasks.

4. Practical work on installations of hardware, software, and landmarks for orientation (if necessary).
5. Testing.
6. Deployment.

It goes without saying that the process does not end after deployment; iterative development will be crucial in order to ensure the system's continued usefulness.

Staff and Policy Issues

To implement these technologies, both management and staff must be committed to the idea that change is positive. To facilitate the implementation process, the project manager should define the objectives of the endeavour clearly, with special attention paid to the length of time the project is expected to be in use. Robots in the cultural heritage sector are unlikely to lead to staff reduction but this might become an issue if long-term, large-scale implementation is planned.

In order to facilitate the introduction of haptics, telepresence and robotics, managers of cultural and scientific heritage institutions can take several practical steps:

- Start with simple, attractive applications. This should help maintain the initial enthusiasm of staff and visitors alike.
- Ensure that the staff responsible for the new applications includes people who are confident (and competent) with new technologies.
- Learn from the experiences of other institutions that have applied the technology.
- Clearly define the goals and criteria for success.

Annexes

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Key Vendors and Suppliers

Selected Glossary

Abbreviations

Permission Statements

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Telepresence, Haptics, Robotics

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Key Vendors and Suppliers

Open Source Software and Standards

Some Major Open Source applications

AbiWord – A word processing program supporting a range of formats: http://www.abisource.com
Apache Web Server – The world's most popular Web server: http://www.apache.org
Filezilla – A fast and reliable FTP client and server: http://filezilla.sourceforge.net
Gaim – An instant messaging client that supports a number of protocols, including MSN, Yahoo and Jabber: http://gaim.sourceforge.net
Gamera: http://gamera.sf.net/
GCC – The Gnu C Compiler, a compiler for the powerful C programming language with front ends and libraries for C, C++, Java, Objective-C, Fortran and Ada, among others: http://gcc.gnu.org
GIMP – The Gnu Image Manipulation tool, a fully featured graphics-editing package: http://www.gimp.org
GNU Emacs – A popular text editor supporting a vast array of formats: http://www.gnu.org/software/emacs/emacs.html
GNU/Linux – The Free/Open Operating System distributed in a variety of packages by a range of vendors (see http://www.linux.org/dist/list.html for a comprehensive list of distributors with details and links)
GRASS GIS – (Geographic Resources Analysis Support System), a Geographic Information System, used for data management, image processing, graphics production, spatial modelling, and visualisation of many types of data: http://grass.itc.it
Greenstone Digital Library Software: http://www.greenstone.org
Icecast – Multimedia Streaming Server, supporting multiple clients and sources: http://www.icecast.org
Koffice – Another office suite, integrated within the popular Linux KDE graphical desktop environment: http://www.koffice.org
MapServer – A development environment for building spatially enabled Web applications: http://mapserver.gis.umn.edu/
Moodle – Virtual learning environment software: http://moodle.org
Mozilla – Fully Featured Web Browser with integrated email: http://www.mozilla.org
Mozilla Firefox – Lightweight standalone Web browser with extensible functionality: http://www.mozilla.org/products/firefox
Mozilla Thunderbird – Lightweight standalone email client with extensible functionality: http://www.mozilla.org/products/thunderbird
Mplayer; Xine – Examples of media players for Linux supporting a range of codecs, including (partial) support for proprietary formats like Windows Media Audio and Windows Media Video: http://www.mplayerhq.hu/homepage/design7/news.html and http://xinehq.de/
MyColex: http://mycolex.collector.ch; http://sourceforge.net/projects/mycolex/

MySQL – Quick Relational Database Management System popular for Web-based deployment. http://www.mysql.com
Novell Evolution – A fully featured email and groupware suite comparable with Microsoft's Outlook Product: http://www.novell.com/products/evolution/
The OpenCD – A range of Windows compatible Open Source Applications: http://www.theopencd.org
OpenOffice.org – The key Open Source alternative to Microsoft's de facto standard Office suite of applications. http://www.openoffice.org
Perl – A powerful scripting language with diverse potential applications: http://www.perl.com
PHP – A powerful, predominantly Web-based scripting language: http://www.php.net
PHPMyAdmin – A comprehensive, Web-based graphical user interface for MySQL: http://www.phpmyadmin.net
Plone and XOOPS – Two powerful Web-based content management system tools: http://www.plone.org and http://www.xoops.org
PostgreSQL – Functionally Rich Relational Database Management System: http://www.postgresql.org
Python – Another powerful, multiplatform-scripting language: http://www.python.org
TightVNC – Virtual Network Computing Server, allowing computers to be fully accessible from remote locations via a Java Applet or TightVNC client application: http://www.tightvnc.com
WINE – "Wine is Not an Emulator", a Windows emulation environment, allowing many Windows applications to run within GNU/Linux: http://www.winehq.org
XMMS – The X Multimedia System, a media player comparable with the Windows program Winamp: http://www.xmms.org
Zope – A server for building content management systems, intranets, portals, and custom applications: http://www.zope.org

Location-based Systems

Company	*Products and Services*	*URL*
Air Flight Services	Photo Library, Digital Imagery, Mapping Photography, Airborne GPS, Airborne Sensor Platforms	http://www.basic.org/gp/afs.html
Apic	*Software products for managing geographic information- engine and generic applications modules*	http://www.apic.fr/indexgb.htm
Autodesk	*GIS software: Map, Map 3D, MapGuide*	http://www.autodesk.com/
Barclay Mapworks Inc.	*Cadastral mapping, map publishing, orthophotos*	http://www.barclaymaps.com/
Bentley Geospatial	*Bentley's mapping solutions deliver powerful, integrated imaging, document conversion, and production mapping.*	http://www.bentley.com/

Company	***Products and Services***	***URL***
Blue Marble Geographics	*Mapping solutions for Coordinate Conversion, Internet Mapping, GPS Interfaces Image, Reprojection Development Tools, Professional Services*	http://www.bluemarblegeo.com/
Cambridge Positioning System	Matrix -3G (E-OTD) system. Matrix – A-GPS system	http://www.cursor-system.com
Caris	*GIS Software for marine solutions, land solutions, learning resources, development tools*	http://www.caris.com/products/
Cell-Loc	Cellocate - a family of products for tracking and asset protection	http://www.cell-loc.com/
Cellpoint	CellPoint positioning system is a digital cellular position-location technology; works with standard GSM phones and WAP phones	http://www.cellpt.com
Corvallis Microtechno-logy Inc.	Manufacturer of GPS/GIS soft-ware and rugged, waterproof handheld computers	http://www.cmtinc.com/
Cquay	Location-Smart – adding loca-tion intelligence for the enter-prise to any corporate database, legacy system, Web solution, or wireless application	http://www.cquay.com
Ericsson Mobile Positioning System (MPS)	MPS is the name of Ericsson's Location Based Services (LBS) solution. MPS consists of a serv-er-based Gateway Mobile Positioning Centre (GMPC), a server-based Serving Mobile Positioning Centre (SMPC) and software extensions for the oper-ator's mobile network.	http://www.ericsson.se
ESRI	GIS and mapping software: ArcView, ArcEditor, ArcInfo, ArcSDE, ArcGIS Server, ArcGIS Engine	http://www.esri.com/
Garmin	GPS receivers	http://www.garmin.com/
Geographic Data Techno-logy Inc.	Development of cartographic data: street, postal, census and other geographic databases	http://www.geographic.com/
GPS Pilot	GPS navigation Palm Software: Atlas, Compass, Fly	http://www.gpspilot.com/

Company	*Products and Services*	*URL*
Guerin Design, LLC	GigaGuide TM is a personal tour guide that delivers photographs, text, oral histories, narration and video on a pocket PC and uses wireless technology	http://guerindesign.com/
HDM (Harvard Design and Mapping)	HDM specialises in Geographic Information Systems (GIS) and provides state of the art location-based technology services.	http://www.hdm.com/
Intergraph	Interactive tools for accessing, analysing and managing geo-linked information	http://imgs.intergraph.com/
MapInfo	*MapInfo offers an extensive portfolio of software products for mapping, routing and geocoding*	http://www.mapinfo.com/
Openwave	Openwave products include phone software, multimedia messaging, Email, location, device management and mobile gateways.	http://www.openwave.com
Oracle	Oracle Database, with Oracle Spatial, Oracle Locator and Oracle Application Server Wireless are location platforms for GIS and LBS vendors.	http://otn.oracle.com/products/
SiRF	GPS chipset and software products	http://www.sirf.com/
SnapTrack	SnapTrack is leader in A-GPS and provides complete technology solutions.	http://www.SnapTrack.com
Star Informatic	*Advanced geospatial technologies*	http://www.star.be/
Starpal	HGIS (handheld GIS)	http://www.starpal.com/
Trimble	*Mapping & GIS, Fleet Management & Vehicle Tracking, Laser and optical positioning systems*	http://www.trimble.com/
TruePosition	TruePosition provides its customers with a full suite of location-based technologies: U-TDOA, A-GPS, E-CID, AOA, and Hybrid.	http://www.trueposition.com/
Webraska	SmartZone -range of applications and enabling technologies: GPS-enabled navigation applications for smartphones and wireless PDAs; GPS-navigation "plug-ins" for fleet management and enterprise mobility applications, maps, wireless location-based services, core geospatial platform technologies.	http://www.webraska.com/

Company	*Products and Services*	**URL**
Wildflower Productions (National Geographic)	*Topo! Software – maps and tools for GIS professionals*	http://maps.nationalgeographic.com/topo/

Comperative Chart of Positioning Technologies

Technology type	*Technology*	*Necessity of equipment or net – work upgrades*	*Positioning Accuracy*	*Time for location determination*	*Cost estimation*	*Technology Scale*
Network based positioning tech-nologies	Cell of Origin (COO)	No	100 m – 30 km	3 sec	Low	Cell network
	Time Difference of Arrival (TDOA)	No	Less than 50 m	n.a.	n.a.	Cell network
	Time of Arrival (TOA)	Additional LMUs	n.a.	n.a.	High	Cell network
	Angle of Arrival (AOA)	Complex antenna array	n.a.	n.a.	High	Cell network
	Radio Propagation Techniques	No	n.a.	n.a.	Low	Cell network
Handset-based positioning technologies	SIM Toolkit CGI + TA (Cell Global Identity) + Time Advance (TA). CGI + NMR (Cell Global Identity) + (Network Measurement Report)	No Modification of SIM-card	Less than 10 m	n.a.	Low Low	Cell network Cell network
	Enhanced Observed Time Difference	Handset upgrade	50 – 125 m	5 sec	Medium	Cell network
	A-FLT (Advanced Forward Link Trilateration) GPS	No	n.a.	n.a.	Low	CDMA network
Global Positioning System	DGPS (Differential GPS)	Satellites, receivers	1-5m	Slow	Medium	Global
	A-GPS (Assisted GPS)	Additional beacons	Less than 1 cm	Slow	Medium	Global
	Accelerometer	Base stations	9m	Fast - A few seconds	Low	Potentially Global
INS (Inertial Navigation	Infrared Ultrasound		Less than 1 cm	Fast	Low	Potentially Global
System) Indoor Positioning systems	RFID		Room	Fast	Low	Room
	Magnetic		9cm	Fast	n.a.	Room
	Radio frequency		Varies	n.a.	Low	Single Location
	lateration		1mm	n.a.	High	Scene
	Ultra-Wideband (UWB) Technology		1-3m	n.a.	High	Building
UWB	Bluetooth IEEE 802.11	Frequency wide-band transceivers		Fast	Medium	Indoor and outdoor
Dedicated networks	Cell ID		1 m	n.a.	Medium	Network coverage
	Statistical IEEE 802.11b (WiFi)		200 m 1 m	n.a.	Low Medium	Network coverage Network coverage
				n.a.	n.a.	

Visualisation of Data

Company	*Products and Services*	*URL*
Tom Sawyer Software	*Tom Sawyer Analysis, Tom Sawyer Visualization* and *Tom Sawyer Layout* provide graph analysis and visualisation technologies.	http://www.tomsawyer.com
Dundas Data Visualization	Advanced Charting, Diagramming and Data Visualisation solutions	http://www.datavisualization.com/home/index.aspx
SPSS	Provides statistical analysis and data mining products for customer analytics, Web footprint analysis, financial risk, organisational intelligence, and survey research.	http://www.spss.com/
Inxight Software, Inc.	Supplier of knowledge extraction and visual navigation components for information-intensive applications	http://www.inxight.com/
Sagent Technology	Offers a business intelligence (BI) software platform that enables business users to access multiple sources of data for analysis.	http://www.sagent.com/
Visual Insights Advizor Solution, Inc.	Provides solutions for business intelligence and application performance management by integrating data visualisation software and analytic business intelligence expertise.	http://www.visualinsights.com/ http://www.advizorsolutions.com/
AISoftware	Develops products for finance, medical imaging, and Internet/Intranet knowledge processing and data intelligence uses.	http://www.ais.it/AISoftw@re/index.asp
Manning and Napier Information Services	Provides clients with online information services for the data mining and analysis of business, financial, industry, technical, newswire, and patent information.	http://www.mnis.net/
I-Impact, Inc.	Provides technology and services for identifying, evaluating, and optimising the economic performance of e-businesses.	http://www.i-impact.com/

Company	*Products and Services*	*URL*
Groxis, Inc.	Provides ***Grokker*** software, which takes search results or metadata and builds knowledge maps containing visual cues and relationships between the data.	http://www.groxis.com/service/grok/
Datawatch Corporation	***Monarch*** data mining software used for report management, mining and data transformation.	http://www.datawatch.com/
VRCO	Provides turnkey visualisation solutions: projected display system, interactive 3D (i3D) visualisation software. Offers a special ***Museum Edition*** designed with capabilities unique to the virtual exhibit needs of museums and science centres.	http://www.vrco.com/
Pixotec, LLC	***Slicer Dicer*** software is designed for scientists, medical professionals, engineers, and other technologists involved with complex data defined in three or more dimensions.	http://www.slicerdicer.com/
SGI	SGI provides solutions in the field of immersive visualisation: high-resolution imagery, real-time interactivity, and immersive visualisation systems. Offers opportunities for museums and science centres to provide their visitors with a unique and educational adventure.	http://www.sgi.com/visualization/
LUST	Data Walls (kiosks) made of Priva-lite that can be switched by electrical current from ordinary-looking clear glass to a whitish translucent glass. Images and information are projected onto the glass panels. Visitors can also trigger more detailed information on the interactive panels and enlarge the images.	http://www.lust.nl
Visual mining, Inc.	***Net Charts Reporting Suite*** – a graphical reporting application for business intelligence.	http://www.visualmining.com/

Company	***Activities and Products***	***URL***
Corda	***OptiMap 6*** – Creates dynamic interactive maps quickly and easily to display any type of geographical data. ***PopChart 6*** – Produces sophisticated interactive charts and graphs with no ActiveX controls or Applets.	http://www.corda.com/
BUSS Limited	**Simpleplot** – family of software tools for data visualisation.	http://www.buss.co.uk/
OCF	Reseller of high performance visualisation (HPV) solutions.	http://www.ocf.co.uk/
NAG Ltd	Produces and distributes high quality numerical, symbolic, and statistical and visualisation software that is robust, reliable and portable across a wide range of hardware.	http://www.nag.co.uk/
STATCON	***Systat*** – Advanced Data Analysis and Data Visualisation software.	http://www.statcon.de/
Advanced Visual Systems	Develops interactive data visualisation software and solutions that help business, scientific and engineering users gain critical insight from all types of data.	http://www.avs.com/
Amtec Engineering, Inc.	Offers ***Tecplot*** data visualisation software, featuring 2D and 3D field plots, XY plotting, and 3D volumetric plots.	http://www.tecplot.com/
Ceetron	***GLview Developer Suite*** – 3D visualisation and image processing software solutions.	http://www.ceetron.com/
Visualize, Inc.	Developer of Java-based data visualisation tools.	http://www.visualizetech.com/
Awaron AG	3D visualisation and modelling software for engineering and virtual reality applications.	http://www.awaron.com/en/index.htm
Idelix	Developers of PDT – Pliable Display Technology, used in 2D and 3D visualisations.	http://www.idelix.com/
Environmental Visualization System	State-of-the art 3D analysis, visualisation, and animation tools integrated into powerful software systems for geologists, geochemists, mining engineers and modellers.	http://www.ctech.com/

Company	Activities and Products	*URL*
Enterprise Dynamics	***Enterprise Dynamics*** – simulation, modelling, and visualisation software to analyse and control dynamic business processes.	http://www.enterprisedynamics.com/
Digimask	Software technology using digital photographs that permits the easy creation of a lifelike 2D or 3D representation of an individual's head that can be animated or distorted in a highly realistic and creative way.	http://www.digimask.com/

Types of chart

Area Chart: depicts the magnitude of change over time. Also shows the relationship of parts to a whole presenting the sum of the plotted values.
Bar Chart (sometimes referred to as a Gantt chart): a graphic representation of quantitative information by means of a drawing made up of parallel bars (horizontal or vertical) with lengths that are proportional to the data being compared.[a] This type of chart is especially popular in project management applications.
Column Chart: shows data changes over a period of time or illustrates comparisons among items. Categories are organised horizontally, and the values placed vertically. Column charts present variation over time in an easy-to-understand way. *Stacked column* charts show the relationship of individual items to the whole.
Line Chart: shows trends in data at equal intervals. Line charts are similar to area charts, but present time flow and the rate of change.
Pie Chart: a visual representation of information showing parts as a proportion, percentage or fraction of the whole using the shape of a circle or a ring and sections of different size within it. The pie charts are convenient for use when a relatively small number of elements should be distinguished. The numerical values could be presented in a table, but the chart gives the idea of proportions of elements.[b]
Doughnut Chart: shows the relationship of parts to a whole, similarly to pie charts, but it can contain more than one data series. Each ring of the doughnut chart represents a data series.
XY (Scatter) Chart: shows the relationships among the numeric values in several data series or plots two groups of numbers as one series of coordinates. It shows uneven intervals, or clusters, of data and is commonly used for scientific data.
Radar Chart: In a radar chart, each category has its own value axis radiating from the centre point. Lines connect all the values in the same series. A radar chart compares the aggregate values of several data series at the same time.
Surface Chart: useful in highlighting the optimum combinations between two sets of data. As in a topographic map, colours and patterns indicate areas that are in the same range of values.

a http://glencoe.com/sec/busadmin/marketing/dp/mktg_resrch/gloss.shtml
b http://www15.hrdc-drhc.gc.ca/awm/main/c_ap_glossary_e.asp

Bubble Chart: a type of x-y (scatter) chart. The size of the data marker indicates the value of a third variable. To arrange data, x values are placed in one row or column, and corresponding y values and bubble sizes are entered in the adjacent rows or columns.
Stock Chart: used to illustrate stock prices. Can also be used for scientific data, for example, to indicate temperature changes.

Telepresence, Haptics, Robotics

Telepresence

Company	*Product*	*URL*
Inetcam	Windows-based audio and video broadcasting solutions that simplify multimedia streaming.	http://www.inetcam.com/
Basic telepresence Inc.	Pan, tilt, zoom cameras, custom enclosures, browser interfaces	http://www.btivideo.com/
iRobot	Wireless remote telepresence robots controlled through Internet (Co-worker)	http://www.irobot.com
Space and naval warfare systems Centre, San Diego	Undersea, air and ground vehicles	http://www.nosc.mil/robots/
Telepresence Systems Inc.	Strategic counsel, design, and system development services	http://www.telepres.com/

Web Conferencing

Company	*Product*	*URL*
Microsoft	**Live Meeting** – an online collaboration and Web conferencing service fully integrated within the new Microsoft Office System.	http://www.microsoft.com
Genesys conferencing	**Meeting Center** – a virtual collaboration platform providing a global audio, Web and video conferencing environment. Based on innovative technologies such as high-speed networking, data compression and load distributing over multiple servers. **Event and Video Services**	http://www.genesys.com

Company	*Product*	*URL*
WebEx	Four Web-based communication services based on a proprietary communication network: **Meeting Center** (suite of services for interactive meetings) **Event Center** (designed for large group events where hundreds or thousands of people are joining an organised event) **Support Center** **Training Center** (supporting live training sessions).	http://www.webex.com
Raindance	**Meeting Edition**: integrated audio, Web and desktop video conferencing tool.	http://www.raindance.com

Interactive Telepresence

Company	*Product*	*URL*
Telesuite	**Enterprise 200** Series Virtual Meeting Room (perfect for small to medium organisations) **Enterprise 400** Series Virtual Conference Room. All products are based on TeleSuite proprietary technology platform called Managed Video Array	http://www.telesuite.com
High Speed Video	**Callervision** system, which utilises existing telephone lines, digital transports such as DSL[c] or fibre optic networks. It consists of a camera, microphone and a dedicated processor serving as a compression and encoding device.	http://www.highspeedvideo.us
Teleportec	**Conference** system, **Lectern** system and custom solutions. All products are based on a proprietary video technology that eliminates the background of the images.	http://www.teleportec.com
Teliris	**Global Table** – an advanced communication platform that delivers CD quality audio, DVD quality video, low latency and real time collaboration tools.	http://www.teliris.com

c Digital Subscriber Line – technology for Internet provision based on the use of commonplace copper telephone lines.

Haptics

Company	*Basic haptic products*	*URL*
SensAble Technologies Inc.	Simulators for surgical training, Phantom (for touching and manipulating virtual objects), SDK for developing touch-enabled applications.	http://www.sensable.com/
Logitech	**iFeel Mouse and the iFeel MouseMan** – Mainstream mice that transmit vibrations when a person scrolls over a hypertext link on a Web page. Operate under Immersion software.	http://www.logitech.com
Immersion Inc.	Touchsense technology, entertainment, medical devices; embedded automotive applications.	http://www.immersion.com/
Novint Technologies	**eTouch Sono** – Converts ultra-sound into haptic reconstruc-tions.	http://www.novint.com/eTouch_Sono.htm
Reachin Technologies AB	Haptic (force-feedback) software components for use in the Medical, Oil & Gas and R&D markets worldwide, Laparoscopic Trainer.	http://www.reachin.se/
ACT Labs	Haptic devices for entertain-ment: arcade games, controllers, force-feedback steering wheels, light guns.	http://www.act-labs.com/
iFeelPixel	Haptic devices for blind individ-uals, alternative of alphabet Braille.	http://www.ifeelpixel.com/

3D Graphic Cards

Company	ATI Techno-logies, Inc. http://www.ati.com/	nVidia http://www.nvidia.com/page/home	Matrox http://www.matrox.com/	ATI Techno-logies, Inc. http://www.ati.com/	SiS http://www.sis.com/	nVidia http://www.nvidia.com/page/home
Card model	Radeon 9800 XT	FX 5950 Ultra	Parhelia - 512	Radeon 9700 Pro	Xabre 600	GF4TI4200
AGP	8x	8x	4x	8x	8x	4x
DirectX	9.1	9.0	8.0	8.0	8.0	8.0
DDR RAM	256 MB	256 MB	128 or 256 MB	128 MB	64 MB	64 MB
Memory clock speed	730 MHz	950 MHz	550 MHz	620 MHz	600 MHz	500 MHz
Core clock speed	412 MHz	475 MHz	220 MHz	325	300 MHz	250 MHz
Memory bandwidth	23.4 GB/s	30.4 GB/s	20 GB/s	10.4 GB/s	9.6 GB/s	8 GB/s
S video or com - posite connector	yes	yes	yes	yes	yes	yes
Approximate price (up to March 2004)	$ 463	$ 430	$ 330	$ 190	$ 125	$ 130

Robotics

Company	***Product areas***	***URL***
ABB Automation Technology, Sweden	Spot welding, material handling, tending, polishing, gluing, picking, packing, palletising.	http://www.abb.se/robotics
Adept Technology, Inc., USA	Electronics, semiconductor, appliances, telecommunications, pharmaceutical, food processing, automotive component industries.	http://www.adept.com
DENSO WAVE Inc., Netherlands	Pick-and-place, assembly, parts loading/unloading, sealing, gluing, handling, palletising.	http://www.denso-europe.com
FANUC Ltd, Japan	Versatile industrial robot, intelligent robot system, including spot welding, dispensing and sealing, paint finish, arc welding, laser processing, material handling, assembly.	http://www.fanuc.co.jp

Company	*Product Areas*	*URL*
Kawasaki Heavy Industries, Japan	Spot welding, arc welding, spray painting, sealant dispensing, adhesive, machine loading, handling, assembling, deburring, polishing, palletising, wafer handling.	http://www.khi.co.jp/robot/
Kuka Roboter, Germany	Industrial applications.	http://www.kuka.com
Staübli Unimation, France	High-speed and precision robots for industrial, painting, clean-room and all automation needs.	http://www.staubli.com/
Gecko systems, USA	Mobile service robots.	http://www.geckosystems.com/
Cybermotion, Inc., USA	Cyberguard surveillance applications.	http://www.cybermotion.com/
Angelus Research Corp., USA	Military Robots, Law Enforcement Robots, Educational Robots, Industrial Robots.	http://www.angelusresearch.com/
Active Media Robotics, USA	Robot guards and guides, robot development software, OEM robot control systems.	http://www.mobilerobots.com/
iRobot	Robotic vacuum cleaner (Roomba), military applications, industrial applications.	http://www.irobot.com/
Via Technologies, Inc, Taiwan	PC bots – convergence PC devices with robotic senses and capabilities.	http://www.via.com.tw/
Aethon	Automated delivery systems for hospitals.	http://www.aethon.com/
White box Robotics	High-end mobile robotic platform.	http://www.whiteboxrobotics.com/
BlueBotics AS	Produce RoboX (interactive tour guiding robot).	http://www.bluebotics.com
HK SYSTEMS	Automated Library System (ALS), cost-effective and space-saving alternative to common document shelving technologies.	http://www.hksystems.com
VideoRay	The smallest produced underwater ROV; can be used up to 500 feet depth.	http://www.videoray.com
iRobot (see also the industrial robots section)	Pyramid Rover (used to study shafts of the Great Pyramid in Giza, Egypt).	http://www.irobot.com/

Selected Glossary

Term	*Meaning*	*Used in Chapter(s)*
Afferent	Conveying inward sensations from external organs to the brain.	Telepresence
Agent	A program that gathers information or performs some other service automatically and on some regular schedule.	Information Retrieval
Boolean	Relating to the system of logic developed by George Boole.	Information Retrieval
Compiling	The process of converting human readable code into the binary code that computers understand.	Open Source
Concatenation	Connecting components together into a longer string.	Natural Language
Corpus (pl. corpora)	A collection of related objects.	Natural Language
Dashboard	A GUI (q.v.) which acts primarily as an editing/control interface.	Visualisation
Data mapping	The transformation of data into different, representative form(s).	Visualisation
Data mining	Analysing data to identify patterns and establish relationships	Information Retrieval
Deep Web	Content accessed through Web pages but held in storage systems such as databases, and therefore inaccessible to search engines.	Information Retrieval
Efferent	Conveying sensations outwardly, e.g. from the brain to motor nerves.	Telepresence
Footprint	The area of the Earth's surface a GPS system can 'see'.	Location-based
Fuzzy search/logic	Considers degrees of truth rather than the usual true or false states and is regarded to be more appropriate in situations which do not translate easily into a binary state, such as natural language and human thought.	Information Retrieval
Geocoding	The process of linking a real place with information about it.	Location-based
Histogram	A graph showing the distributions of data values.	Information Retrieval

Term	*Meaning*	*Used in Chapter(s)*
Kludge	An unsatisfactory, although effective, fix to a software problem.	Open Source
Linux distribution	A software package containing the Linux Kernel, GNU tools and a range of other Open Source software.	Open Source
Matrix	A set of values laid out in tabular form.	Information Retrieval
Morphology	The study of word structure	Natural Language, Information Retrieval
Multimodal	Allowing the simultaneous use of multiple input and output devices.	Natural Language
Occlusion	A visual obstruction where one object shields another from view.	Visualisation
Ontology	A machine-readable specification for knowledge transfer within a certain concept.	Natural Language
Operating System	The central program within a computer system, communicating at a very low level with the microprocessor and other hardware and organising the execution and run-time of each program.	Open Source
Parallax	The visual shifting of an object when viewed from different positions.	Visualisation
Parsing	Dividing a string (q.v.) into separate component parts.	Open Source, Natural Language
Prosodic	Relating to the rhythmic aspect of language.	Information Retrieval
Raster	A type of image where every pixel is recorded.	Location-based
Relevance threshold	The point at which an object is deemed to be relevant in 'best match' IR systems.	Information Retrieval
Remote sensing	The collection of information about an object or event without any physical contact taking place between the collector and the object.	Telepresence
Servlet	A small Java program running on a server.	Open Source
Source code	Human Readable programming code that is subsequently compiled (q.v.) into machine-readable binary code.	Open Source

Term	*Meaning*	*Used in Chapter(s)*
Spyware	Unsolicited software that gathers information about a user without their knowledge or consent.	Open Source
String	A continuous sequence of characters.	Information Retrieval
Syntactical	Relating to the way in which words or other elements of sentence structure are combined to form grammatical sentences.	Information Retrieval
UNIX	Standard grouping for operating system software that follows the design conceived at AT&T's Bell Laboratories.	Open Source
Vector	A type of image where only positional and directional data are recorded, such as the beginning and end co-ordinates of a line.	Information Retrieval, Location-based
Wiki	A collaborative database that can be viewed and edited by any user.	Open Source

Abbreviations

Abbreviation	*Stands for*	*Used in Chapter(s)*
2G	Second Generation	Location-based
3G(PP)	Third Generation (Partnership Program)	Location-based
A-FLT	Advanced Forward Link Trilateration	Location-based
A-GPS	Assisted Global Positioning System	Location-based
AOA	Angle Of Arrival	Location-based
ASP	Application Service Provider	Information Retrieval
ASR	Automatic Speech Recognition	Natural Language
ASRS	Automated Storage and	Telepresence
	Retrieval System	
BI	Business Intelligence	Visualisation
BTS	Base Transceiver Station	Location-based
CAD	Computer-Aided Design	Telepresence
CAT	Computer-Assisted Translation	Natural Language
CBIR	Content-Based Information	Information Retrieval
	Retrieval	
CCD	Charged Couple Device	Telepresence
CDMA	Code-Division Multiple Access	Location-based
CES	Corpus Encoding Standard	Natural Language
CGI	Cell Global Identity	Location-based
CLIR	Cross-Lingual Information	Information Retrieval
	Retrieval	
CMF	Common Metadata Framework	Information Retrieval
COO	Cell Of Origin	Location-based
CVS	Concurrent Version System	Open Source
DAMS	Digital Asset Management	Information Retrieval
	System	
DBMS	Database Management System	Location-based
DGPS	Differential Global Positioning	Location-based
	System	
DSP	Digital Signal Processing	Information Retrieval
E-OTD	Enhanced Observed Time	Location-based
	Difference	
FAQ	Frequently Asked Questions	Open Source
FS(F)	Free Software (Foundation)	Open Source
FUD	Fear, Uncertainty and Doubt	Open Source
GCC	GNU C Compiler	Open Source
GIS	Geographic Information System	Location-based, Visualisation
GMLC	Gateway Mobile Location	Location-based
	Centre	
GNU	Gnu's Not Unix	Open Source

Abbreviation	*Stands for*	*Used in Chapter(s)*
GPL	General Public License	Open Source
GPR	Ground Penetrating Radar	Location-based
GPS	Global Positioning System	Location-based, Visualisation
GUI	Graphical User Interface	Visualisation, Telepresence
HCI	Human Computer Interaction	Natural Language
IE	Information Extraction	Information Retrieval
IM	Instant Messaging	Open Source
INS	Inertial Navigation System	Location-based
IP	Intellectual Property	Open Source
IR	Information Retrieval	Natural Language, Information Retrieval
IRC	Internet Relay Chat	Open Source
IVR	Interactive Voice Response	Natural Language
KWIC	Keyword In Context	Information Retrieval
LAMP	Linux/Apache/MySQL and PHP, Perl or Python	Open Source
LAN	Local Area Network	Location-based
LBS	Location Based System/Service	Location-based
LCD	Liquid Crystal Display	Visualisation
LDT	Location Determination Technology	Location-based
LGPL	Lesser General Public License	Open Source
LIF	Location Interoperability Forum	Location-based
LMU	Location Measurement Unit	Location-based
MeSH	Medical Subject Headings	Information Retrieval
MPC	Mobile Positioning Centre	Location-based
MTBF	Mean Time Between Failures	Telepresence
NLP	Natural Language Processing	Natural Language, IR
NLU	Natural Language Understanding	Natural Language
NMR	Network Measurement Report	Location-based
OAI-PMH	Open Archives Initiative Protocol for Metadata Harvesting	Information Retrieval
OCR	Optical Character Recognition	Information Retrieval
OGC	Office of Government Commerce	Location-based
OPAC	Online Public Access Catalogue	Information Retrieval
OSI	Open Source Initiative	Open Source
OSS	Open Source Software	Open Source
OWL	Web Ontology Language	Natural Language
PDA	Personal Digital Assistant	Natural Language, Location-based, Visualisation
PHP	PHP Hypertext Preprocessor	Open Source
PIN	Personal Identification Number	Natural Language
RFID	Radio Frequency Identification	Natural Language, Location-based, Visualisation, Telepresence

Abbreviation	*Stands for*	*Used in Chapter(s)*
ROI	Return On Investment	Visualisation
ROV	Remotely Operated Vehicle	Telepresence
RSI	Repetitive Strain/Stress Injury	Natural Language
SDK	Software Development Kit	Visualisation
SGML	Standard Generalised Markup Language	Information Retrieval
SIM	Subscriber Identity Module	Location-based
SQL	Structured Query Language	Open Source
SVG	Scalable Vector Graphics	Visualisation
SYMAP	Synagraphic Mapping System	Location-based
TA	Time Advance	Location-based
TCO	Total Cost of Ownership	Open Source
TDOA	Time Difference Of Arrival	Location-based
TEI	Text Encoding Initiative	Natural Language, Information Retrieval
TOA	Time Of Arrival	Location-based
TTS	Text-to-Speech	Natural Language
UMLS	Unified Medical Language System	Information Retrieval
UNIMARC	Universal Machine Readable Catalogue	Information Retrieval
UWB	Ultra-Wideband	Location-based
VE	Virtual Environment	Telepresence
VLE	Virtual Learning Environment	Open Source
VNC	Virtual Network Computing	Open Source
VR	Virtual Reality	Telepresence
VTS	Vehicle Tracking Services	Location-based
W3C	World Wide Web Consortium	Location-based
WINE	Wine is Not an Emulator	Open Source
WYSIWYG	What You See Is What You Get	Telepresence
XML	Extensible Markup Language	Natural Language, Information Retrieval, Location-based
XMMS	X Multimedia System	Open Source

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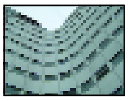

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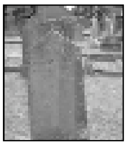

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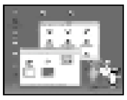

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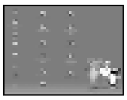

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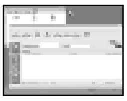

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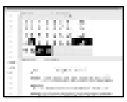

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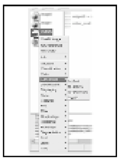
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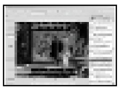
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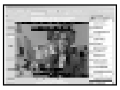
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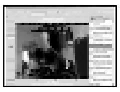
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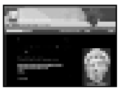
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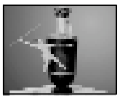
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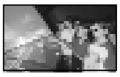
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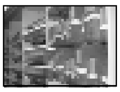
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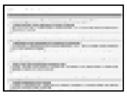
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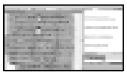
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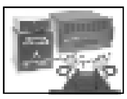
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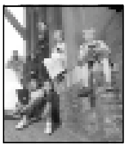

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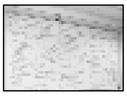

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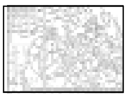

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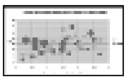

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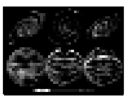

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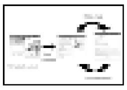
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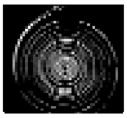
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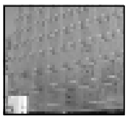

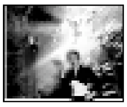
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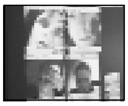
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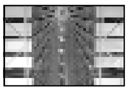
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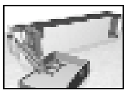
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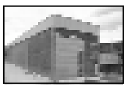
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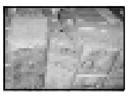

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